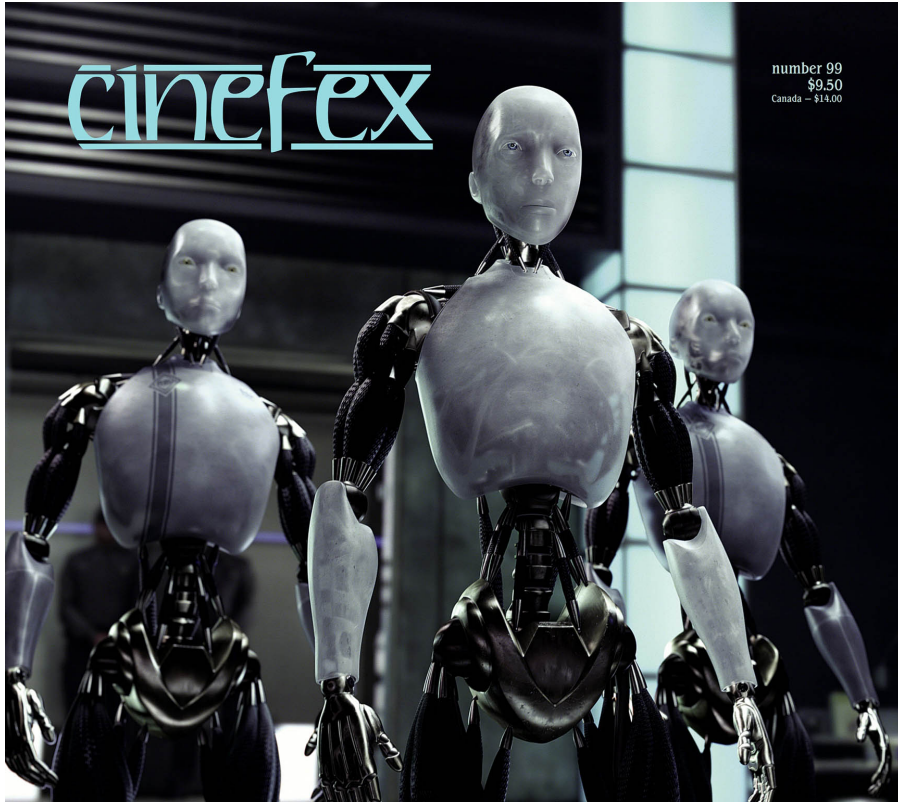


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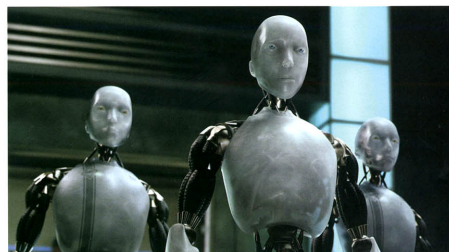
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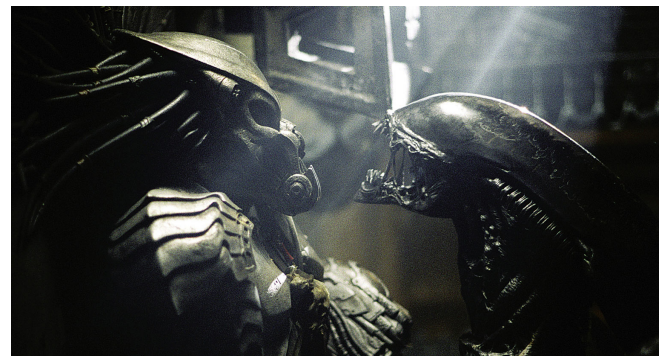
ARTICLE BY JODY DUNCAN

Sooner or later, flies on the walls of dormitories, locker rooms and neighborhood bars are privy to heated debates over which monster icon can lay claim to the title of Supreme Bad-Ass of the Universe. Spirited arguments erupt over who would win in a battle between *Frankenstein* and the *Wolfman*, the *Hulk* and the *Thing*, the *Terminator* and *RoboCop* ...

It was just that kind of amusing speculation that inspired contests between two of moviedom's fiercest creatures in a series of comic books, videogames and, most recently, in a feature film release from Twentieth Century Fox. In this corner: the alien biomechanoid introduced in Ridley Scott's 1979 blockbuster, *Alien*. In this corner: the extraterrestrial big-game hunter who targeted two future governors in 1987's *Predator*.

Predator and Prey

ARTICLE BY JODY DUNCAN



The notion of pitting warriors from the *Alien* and *Predator* films against one another had met with success in a series of comic books and videogames, but a film rendition of *Alien Vs. Predator* languished in development at Twentieth Century Fox for ten years. Director Paul W.S. Anderson finally jump-started the project with a screenplay that brought the aliens to contemporary earth, bred as the ultimate prey for adolescent predators performing rites of passage. Alec Gillis and Tom Woodruff, Jr. of Amalgamated Dynamics Incorporated – longtime contributors to the *Alien* franchise – realized all of the film's on-set creature effects with makeups, suits and animatronics.

Given the success of the videogames and comic books, there was considerable commercial motivation for pitting these two hugely popular warriors against each other in a feature film; and yet, it took ten years to bring *Alien Vs. Predator* to the screen. Scripts and directors came and went over that decade, with Fox never quite satisfied with the direction of the storyline — until director Paul W.S. Anderson took his shot. “My idea was quite different from the previous *Alien/Predator* concepts,” Anderson said. “All of the earlier scripts had put the predator in the world of the alien — out into space, in the far future. My story situated the alien in the contemporary earth world of the predator, creating the opportunity for the alien to interact within the world as we know it. It was a fresh idea that excited the studio. There had already been four *Alien* movies with the creature running around on spaceships; and you can do spaceship corridor chases only so many times before they become a bit generic and boring.”



The Moving Picture Company, Double Negative, Framestore CFC, Cinesite and UPP Prague collaborated to generate nearly 500 visual effects shots for the film. All of the companies worked under the guidance of visual effects supervisor John Bruno, producing their shots in a feverish, three-month-long postproduction. A key flashback scene, created by MPC, features hordes of aliens attacking predators on an ancient pyramid. Many of the flashback shots were entirely digital, with alien swarms – controlled via MPC’s in-house crowd system – climbing atop 3D structures.

The ‘aliens on earth’ idea had intrigued Anderson since adolescence. “When my friends and I went to see *Aliens*,’ Anderson recalled, “we all just knew that the alien was in the cat from the first movie — so we were all waiting for the cat to explode with the chest-burster during that opening sequence at the Gateway station. Of course, that didn’t happen — although Jim Cameron made you think it was going to happen. Then, when *Alien 3* came out, the trailer had the tag line: ‘This Christmas, you’ll discover that on earth, everyone can hear you scream.’ So my friends and I were thinking: ‘Ah, great, finally! The aliens are coming to earth!’ But, of course, it didn’t happen in *Alien 3*, either. In *Alien Resurrection*, they kind of got to earth by the end of the movie — but you didn’t care by then. Just remembering how excited I’d been by the prospect of the alien being on earth, I thought this story idea could generate that same kind of excitement.”

Anderson’s story has a group of scientists commissioned by industrialist Charles Weyland Bishop (Lance Henriksen) traveling to Antarctica to investigate mysterious underground activity there. The team, led by guide Lex Woods (Sanaa Lathan), discovers an ancient subterranean pyramid in which a captive alien queen lays eggs, producing progeny that serve as the ultimate prey for adolescent predators executing a rite of passage into manhood — an idea presented in the first *Alien Vs. Predator* comic book. Trapped inside the pyramid, the human team is caught in the crosshairs of the battle between the aliens and three recently arrived predators.

Visual effects would play a critical role in the film, whose production was based in Prague, with The Moving Picture Company, Cinesite, Framestore CFC, Double Negative and a local Czech company, Universal Production Partners – Prague, all providing shots under the leadership of visual effects supervisor John Bruno. Most of the creature work would be realized practically, through suits and

animatronics created by Amalgamated Dynamics Incorporated. A.I founders Tom Woodruff, Jr. and Alec Gillis had been integral to the *Alien* franchise since working on *Aliens* at Stan Winston Studio. After branching out on their own, the two had supplied the creatures for *Alien 3* and *Alien Resurrection*, with Woodruff himself suiting up to portray hero aliens.

The in-camera creature effects concept for *Alien Vs. Predator* was mandated by a limited budget and a schedule that was severely truncated on the front and back ends, leaving little time for preproduction and only three months for post. “When I was approached with this project,” recalled John Bruno, “the first thing I heard was, ‘Can you do it in under a year?’ And I said, ‘Well, yeah, if there’s enough money.’ And they said, ‘There is no money.’ So I told them that we’d have to do as much in-camera as possible. With only three months for postproduction, there wasn’t going to be time to do a lot of CG effects. The decision was to try to do everything as a practical effect — and then, whatever couldn’t be done that way, we’d do in post with visual effects.”

Even if granted more time and money, Anderson and Bruno would have leaned toward the practical approach — the former because of a general dissatisfaction with computer generated characters, and the latter because of a career-long propensity to keep visual effects shots down to an absolute minimum. “John is one of those visual effects supervisors who will do anything to avoid doing visual effects,” Anderson observed, “and I love that about him. The great example of that is *True Lies*, where they had to get a Harrier jet to fly around a skyscraper. John’s solution to that was to get a real Harrier jet, stick it on a crane and dangle it over a real skyscraper! And it looked great. I really like that sensibility.

“Also, I was personally disappointed in the CG in *Alien Resurrection*. I thought you could really tell when the aliens were CG and when they weren’t. So, we decided to save our CG only for those shots we couldn’t accomplish any other way. We even shot the big, stunt-heavy fights between the aliens and the predators practically first, hanging guys on wires, shooting in reverse, whatever we could do. The result was that instead of having 1,500 visual effects shots, we had about 500 — which meant we could put our efforts into making each of those as good as possible.”



Cinesite assembled a shot in which an ice-breaker ship delivers a team of scientists to Antarctica. Shot elements included a model ship and helicopter, built and shot by the production miniatures unit. Cinesite composited the model photography with a matte-painted sky and CG ice set extensions, and added CG blades to the helicopter model.

Practical effects had performed admirably as a means of realizing the creatures in all the previous *Alien* and *Predator* movies. The predator had been played by a performer in a suit and mechanized head, designed by Stan Winston Studio. In *Alien*, the monster — designed by H.R. Giger — had been portrayed by a tall, thin performer wearing a black rubber suit and a cable-operated head built by Carlo Rambaldi, with mechanized puppets representing the face-hugger and chest-burster ‘baby’ alien. In *Aliens*, the rubber suit was replaced with a more flexible stretch-fabric suit, onto which Stan Winston Studio crew members glued foam latex pieces, with a fitted mechanized head atop the performer’s own. Winston Studio also produced a quarter-scale, cable-operated alien queen puppet, and a giant full-scale version, operated through hydraulics, cables and puppeteers positioned inside the creature’s abdomen. Collaborating with A.I., *Alien 3* director David Fincher had gone with the proven man-in-a-suit approach, enhancing the in-camera effects with motion-controlled 1/3-scale rod puppets composited into live-action scenes by Boss Film Studios. The first fully-CG aliens made brief appearances in *Alien Resurrection*; but, again, the majority of the creature work was accomplished by the A.I crew, which improved upon the alien with new silicone materials and state-of-the-art animatronics.



A member of the model crew dresses the set prior to shooting the miniature ship. The severely truncated postproduction schedule required the miniatures unit – supervised by Richard Van Den Bergh – to work concurrent with the first and second units.

All of this knowledge and past experience came to bear on the *Alien Vs. Predator* production as Anderson began planning his movie, refining the script, and developing visual concepts. As part of that process, Anderson and his visual consultants reconsidered the design of the aliens and the predators. The look of the aliens, in particular, had evolved from one film to the next, as each successive director put his own stamp on the original design. Anderson’s inclination was to return to that first alien for his film. “Giger’s design was genius,” Anderson stated, “and my attitude was, ‘Don’t fuck with genius.’ *Aliens* is an incredibly entertaining and well-crafted film, and I’ve probably seen it 150 times; but, in terms of the alien itself, I didn’t think it looked as good as it had in *Alien*. I also wasn’t keen on the dog-like look of the alien in *Alien 3*. In *Alien Resurrection* the aliens looked more like beasts than the biomechanoid that Giger had created. For our movie, we wanted to return the aliens to that dark, oily, biomechanoid that Ridley Scott had portrayed so well in *Alien*.”

The darker coloring, in addition to reflecting the original alien design, would also help Anderson hide and camouflage the character within production designer Richard Bridgland’s obsidian-black pyramid chamber sets. “It is not easy to hide organic forms within architectural lines,” noted Alec Gillis. “The coloring helped with that. Richard Bridgland also cleverly incorporated repeating alien textures in the chamber walls.” To define the overall black creature and give it a metallic quality, A.I designed a paint scheme with silver highlights and washes of copper and bronze. Additional design

refinements included slightly larger hands — to avoid their looking inappropriately small when in proximity to the massive predator head — and a redesign of the alien suit closures that would enable Tom Woodruff and stunt performers to get in and out of it more quickly.

The alien queen would be modified, also, to more closely reflect the design director James Cameron had conceived for her debut appearance in *Aliens*. “In Cameron’s original sketches,” explained Anderson, “the queen was much more insectoid, with an impossibly thin waist area. But, at the time, he wasn’t able to get exactly the queen he sketched. To operate the full-scale version, they’d had to put two puppeteers in the chest area, and Stan Winston’s guys had to bulk up the queen to make room for them. Then, with the quarter-scale puppet, because there was no such thing as rig and wire removal at that time, they’d had to very tightly pack all of the cabling inside the creature, which led to some herky-jerky movements. It compromised what the queen could do because there was a limit to how many wires you could run inside it. For our queen puppet, we could run any number of rods and wires to it, on the outside, because all of them could be removed later. Technology had moved forward since *Aliens*, and we took advantage of that.”

In addition to giving the queen a more insect-like thorax, A.I. made some minor changes to her overall lines and lengthened her neck to increase her range of movement. “With a longer neck,” said Gillis, “we could get more parallelogram action, more points of movement for greater expression. We reworked the face, as well — but only subtly. We consider ourselves caretakers of these creatures. We inherited these designs; and so our goal wasn’t to ‘fix’ what wasn’t broken, but to create a sense that there was something new and fresh about these characters.”

Like the alien, the design of the predator remained essentially true to the look of the character in the first movie. The lead predator, Scar, would sport the classic predator faceplate, while his two comrades would wear faceplates with subtle differences so that the audience could tell one from the other. A slight redesign of the body suit supported one of the



Paul Anderson took a purist’s approach to the look of the aliens and predators, implementing only minor changes to the characters’ original classic designs. Among the subtle predator modifications was an increase in body armor – protection against an adversary far more formidable than those in Predator 1 and 2 – and slightly more heroic body proportions, as befitted the lead predator’s ‘white-hat’ role in the film.



A.I. finishing artist Ginger Anglin fits teeth into a foam latex predator head casting. The final hero makeup included an articulated, radio controlled mask that provided a full range of expression.

movie's surprising story points — the teaming of Lex and Scar against the aliens. "This predator becomes a hero," noted Gillis, "and so there had to be a nobility about him. We looked at him as a leading man, not just the scary, bad-ass guy we'd seen previously. He still had to be a scary, bad-ass guy, but we toned that down, partly by using less slime on him than had been used in the past." The physique of Scar performer Ian White also lent itself to the heroic predator concept. "Ian was a former basketball player whose physique was just perfect to work over. He had a lean, V-shaped body to begin with, which enabled us to go for more heroic proportions in the predator."



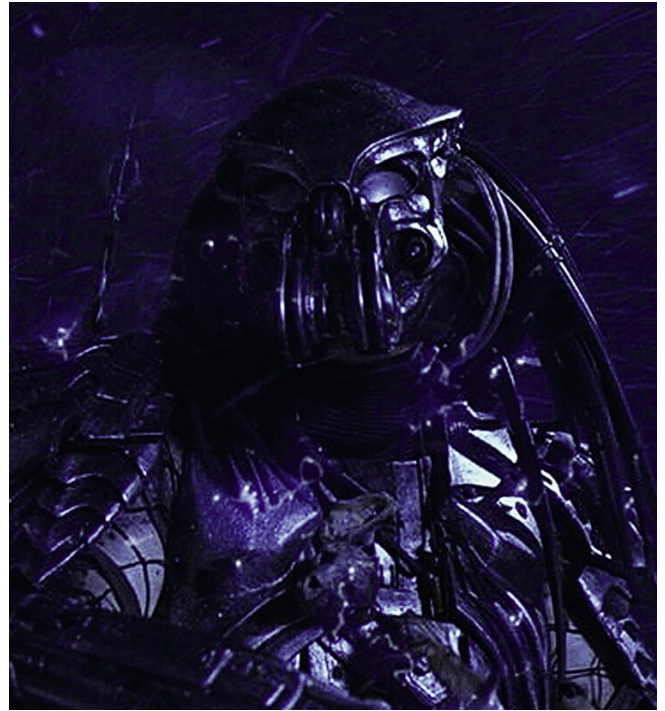
Double Negative took advantage of current technology to improve upon the predator cloaking effect, previously achieved by optically manipulating an element of an on-the-set predator performer in a greenscreen suit. For the updated cloaking effect, crews shot the fully made-up and wardrobed predator against a section of greenscreen, isolated that element and placed it in front of a clean background plate that was distorted through volumetric displacement. To give the cloaking effect a more organic feel, the images were broken up with fractal noise patterns or by offsetting individual red, green and blue channels.

Another design decision driven by the storyline was that the predators would wear significantly more armor than their predecessors. “We figured that, for the predators, hunting Arnold Schwarzenegger and Danny Glover had been like hunting squirrels,” Anderson noted. “When you hunt squirrels, you don’t need that much armor; but when you hunt aliens, you know there is going to be acid blood spraying around, so you need more of it.” The same reasoning led to the design of bigger and more sophisticated weapons than those seen in *Predator* and its sequel. “It takes more to put down an alien than it does to put down Jesse Ventura.”

In the weeks leading up to principal photography, A.I. translated the redesigns into a staggering array of creature effects elements. Shipped to Prague were one hydraulic alien warrior, one insert alien attack head, more than 30 full-body alien and predator suits, 14 sets of predator armor, seven servo-articulated heads — two for the predator and five for the aliens — five hand-puppet face-huggers, six floppy face-huggers, one fully articulated animatronic face-hugger, several cable-operated and floppy chest-bursters, 10 articulated alien eggs and another 20 positionable ones, numerous alien stunt tails and heads, three miniature alien queens, a full-size hydraulic motion control queen and various mechanical predator weapons.

Fabrication and repair work continued throughout the four-and-a-half-month shoot — an especially labor-intensive period for all of the effects crews, due to a brutal schedule that often had up to four units working simultaneously. “In order to meet our deadlines,” said John Bruno, “we had to complete the miniatures at the same time we finished first unit and second unit, which meant it all had to be done at the same time. I was constantly going from one unit to another — 15, 16 hours a day, seven days a week.”

Miniatures supervisor Richard Van Den Bergh oversaw the model project, which included a miniature ship, built in the U.K. by Bill Pearson, and nine full miniature sets. Among them was a 1/6-scale whaling station for an end sequence in which a predator bomb — set off in the ice tunnel leading to the underground pyramid — causes the entire 32-building complex and the ice plain around it to collapse. “One-sixth-scale was the largest we could build this set at that studio,” said Van Den Bergh. “Individual buildings were built in precut wood and placed on layers of pattern-cut polystyrene. There were five generic shapes of polystyrene that we could fit together to create



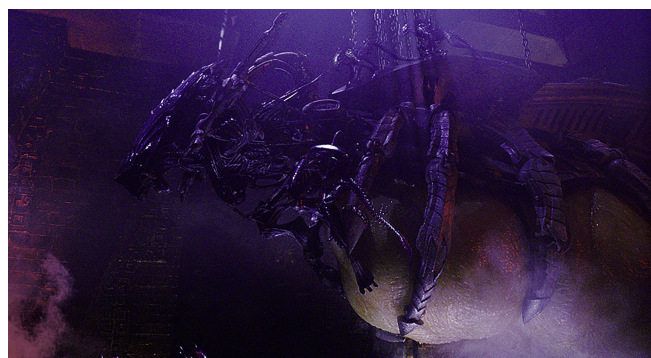
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prescored structures that would collapse in a certain pattern. We dressed the buildings and the ground in sheets of UF?foam and dendritic salt to make the miniature look as if it was covered in ice and snow.”

Situated on a motorized tabletop rig that measured 92 feet by 40 feet, the miniature collapsed in a sequential wave of destruction with the push of a button. “The table would drop,” said Van Den Bergh, “releasing a series of weights at the ends of wires that went through the miniature buildings. When the weights dropped, they pulled down the buildings sequentially.” The collapse was shot three times. Each reassembly of the miniature’s 8,000 pieces consumed more than two weeks’ time. Double Negative composited the final shot, blending the miniature photography with live-action, greenscreen elements, practical atmospheric elements and computer generated ice cracks.

The miniatures crew also built a 1/24-scale pyramid and cave miniature for the first awe-inspiring reveal of the structure. The pyramid itself measured 16 feet tall and 24 feet wide at its base, and was made of medium density fiber wood with sculpted detail. The cave surrounding the pyramid was made out of clear fiberglass so that visual effects director of photography Peter Talbot could light it from behind to create an ambient glow. Generic cave sections were built in separate pieces so they could be moved around the two-sided pyramid miniature as needed, depending on shot composition and camera angle.

The egg chamber in which the alien queen is first revealed was built both as a partial full-scale set — for shooting live-action with the actors and A.I.’s full-scale hydraulic queen — and in 1/3-scale for shots utilizing the 1/3-scale queen puppet. The egg chamber miniature featured a working ‘queen machine’ — an instrument of torture that holds the queen captive, forces her to lay eggs via electrical charges, then deposits the eggs on a conveyor belt. Electrical charges were animated in postproduction; but other elements of the machine, such as the conveyor belt and an arm that takes the eggs from the queen’s ovipositor, were functional, operated through winches and rods. “Richard Van Den Bergh’s crew, in only four days, made these articulated 1/3-scale ‘hands,’” recalled John Bruno. “They also made a new armature that allowed the queen to be puppeteered from



In an ancient pyramid hidden beneath the Antarctic ice shelf, alien warriors aid their captive queen in escaping the ‘queen machine,’ a predator-designed constraining device that harvests the creature’s eggs. The shot featured a 1/3-scale queen and rig, built by A.I. and the model crew and shot on a 1/3-scale set. The Moving Picture Company composited the shot, adding CG aliens climbing atop the queen puppet, as well as chains, smoke and atmospheric effects to flesh out the model photography.



The crew prepares to shoot the 1/3-scale puppet and queen machine setup. For the queen design, Anderson and the A.I. team referenced Aliens director James Cameron’s original concept sketches – a spindly, insectoid design that, ultimately, had been bulked up to accommodate two puppeteers positioned within the full-size queen’s abdominal cavity. Modern wire and rig removal techniques negated the need for internal puppeteers, allowing the AVP team to create a queen that more closely resembled Cameron’s original vision.

behind the walls of the set, and they did much of the puppeteering themselves, as they were all former Henson puppeteers.” To give the overall setup more movement, the model crew replaced the original A.I fiberglass egg sac with a more flexible silicone version. Servos inside the fiberglass core of the sac made it undulate and gave the entire machine some movement.

A.I had built the queen puppet first in 1/4-scale — the same used in *Aliens* — but rebuilt her in 1/3-scale when John Bruno learned of problems the *Aliens* effects crew had encountered. “I talked to Pat McClung and Bob and Dennis Skotak,” said Bruno, “all of whom had worked on *Aliens*, and they all mentioned that if the queen had been a foot taller and eight inches longer, they would have been able to get more depth of field out of it. So we had Tom and Alec resculpt the queen in 1/3-scale. It was a bit scary to play around with the queen, because that was Jim Cameron territory — and I knew I would have to answer to Jim if I screwed up his queen.” A.I supplied production with two 1/3-scale alien queens — one rod puppet with a servo-operated mouth, the other a cable-and-servo puppet that could be mounted on a boom arm for shots of the queen from the waist up.

For interactive shots with the live actors, A.I built a full-scale, hydraulic, motion-controlled queen that stood 20 feet tall when fully erect and sported an eight-foot-long head. To build the full-scale queen, Woodruff and Gillis borrowed *Aliens*’ original full-size queen head from film memorabilia collector Bob Burns. “We couldn’t actually use that head,” noted Gillis, “because it was very heavy and clunky, built in 1985. But we thought we might be able to add to it sculpturally — which is what we did. Using that head as a base, we sculpted on it, remolded it and cast our own lightweight version in fiberglass. Then, for the body, we had our 1/3-scale queen scanned, and produced a full-scale foam version. We refined that sculpturally, molded it, and cast our full-scale pieces.” The hydraulic full-scale queen was operated through Steven Rosenbluth’s Overdrive system. “Overdrive is a beautiful motion control system that allows you to edit, record, play it in slow motion, play it in reverse — anything you can think of.”

Overdrive also drove a full-size hydraulic version of the alien warrior. “The hydraulic was a whole warrior from the knees up,” stated Tom Woodruff. “It had more points of movement, faster movement, and more forcible movement than what we could get with the human-worn head. For example, the hydraulic head could strike like a cobra, which was something the human-worn head wasn’t capable of doing, because there was no way to fit those mechanisms in there with a human inside.” In addition to providing repeatable and more forceful movement, the hydraulic warrior was useful for spelling the human alien performers in some shots. As the lead alien performer who spent more time in the suit than anyone, Woodruff especially welcomed the on-set stand-in. “It was great for me to be able to perform the alien with only these little handheld joystick controls. It was a completely new experience to just lay down the controller and walk away when we finished a shot. I could actually go to lunch or go to the bathroom — neither of which I could do in the suit and head.” For extreme closeups not requiring the full warrior body, A.I built a handheld insert attack head, rigged with a piston tongue that could fire in and out.

While the hydraulic was useful for specific types of shots, most hero shots of the alien were still performed by Woodruff, wearing a suit A.I had refined in its nearly 20-year association with the *Alien* franchise. For *Aliens*, foam latex alien shell pieces had been glued onto a lycra unitard. Since *Alien 3*, however, A.I has run the foam rubber against the fabric of the unitard, creating a stronger

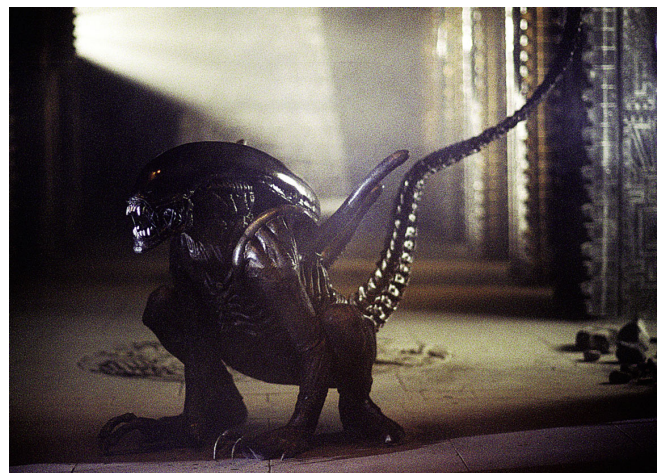
bond and avoiding the added thickness of a layer of glue. “The unitard was actually bonded with the foam rubber,” stated Woodruff. “When we pulled it out of the mold, it was a one-piece thing, with the soft foam rubber sculpted surface on the outside, and the strong lycra foundation on the inside.”

Atop the suit, Woodruff wore an articulated hero head — a fiberglass understructure covered in a clear vacuform dome. A final face appliance attached to the front of the dome and was blended into the head with paint. Radio control mechanisms provided facial movement, particularly in the creature’s pliable mouth area. “The hero animatronic head that I would wear had a jaw that opened and closed,” said Woodruff. “It also had lip mechanisms with multiple points of attachment and multiple points of movement to give us a range of fluidity.”

A.I. also fashioned two types of nonarticulated stunt heads — one featuring the translucent vacuform dome, and another with an opaque, but stronger polyurethane dome that was better able to endure damage inflicted during fight scenes. One of the difficulties in building the stunt heads was that A.I. did not have access to the actual stunt alien performers — most of which would be Prague locals — during the build. As a result, A.I. had to build generic stunt heads that could be adapted to fit nearly any head size. “Part of what made the aliens work so well in the past was our ability to cast the head of the performer and make a very sleek, form-fitting skullcap,” Woodruff commented. “We would build the alien head over the top of that, with a minimum of extra volume in the alien neck where the performer’s head would go. This time, since we didn’t have the stunt performers available to us, we built slightly oversized fiberglass skullcaps, then added padding inside to retrofit them to different head sizes.”

As in all of the *Alien* films, the creature’s complex reproductive cycle required additional alien effects: the face-hugger that leaps out of an egg and onto the head of its victim, its phallic appendage forcing itself down the throat to plant the alien seed, and the alien baby that grows from that seed and is born in a violent burst from the victim’s chest.

Most of *Alien Vs. Predator*’s face-hugger effects would be accomplished on set with A.I. floppy or animatronic puppets. “Our hero face-hugger was built using radio control mechanisms that enabled us to articulate all eight of its fingers,” said Woodruff. “It was on the end of a long control arm that could support the weight of it — so the weight of the puppet wasn’t actually on the fingers — which allowed us to use an articulated mechanism that was capable of a wide range of movement. Each finger had three points of movement, and there was also movement at the base; and so, when it was puppeteered properly, the fingers looked like they were actually propelling the creature, rather than just doing general movement.”



As he had in previous Alien films, Tom Woodruff performed hero alien shots, wearing an articulated headpiece and a foam-and-lycra suit – both of which had been refined over the course of Woodruff’s and Gillis’ nearly 20-year involvement in the Alien franchise. Slight redesigns of the suit for AVP included a darker coloring to better camouflage the creature in the shadows of the pyramid interior, larger hands, and new closures that enabled Woodruff and stunt performers to get into and out of the suit more quickly.

For a wide shot in the egg chamber that reveals multiple face-huggers emerging from multiple eggs, A.I. employed five face-hugger hand puppets. “A puppeteer could just reach up from inside the egg with a face-hugger puppet on his hand,” explained Woodruff, “until we saw the top half of the face-hugger crest the opening of the egg.” Leaping face-huggers were computer generated, while subsequent shots of face-huggers attached to faces were achieved with A.I. floppies. “We had bladders built into them, operated by the actor breathing in and out to make the face-hugger pulsate.”

Chest-bursters were cable-operated, as they had been in the previous movies, but featured a new cable-operated tongue that could execute fast, darting movements. Floppy chest-bursters were attached to wires and manually pulled across the floor to create a writhing motion. Animated Extras provided dummy chest-burster victim bodies, which A.I. modified to spray blood during a pickup shoot. A.I. also provided a cable-operated hybrid alien/predator chest-burster that appears at the end of the film.

While all of the alien-related effects were well-traveled territory for A.I., the predator effects were less so. Gillis and Woodruff had been only peripherally involved in the production of the first predator suit at Stan Winston Studio, and the team had not worked on *Predator 2* at all. For *Alien Vs. Predator*, A.I. had to quickly get up to speed on previous predator effects, while also improving on them. “The predators not only had more screen time in this movie than they’d had in the other *Predator* movies,” observed Gillis, “the stunt requirements were much more strenuous — so we had to make suits that could stand up to all of that.”

The hero predator makeup started with an articulated mask that fit over Ian White’s head, mounted to a custom-fit skullcap. Made of fiberglass covered in a layer of foam latex skin, the mask was packed with 27 servos to provide a full range of expression — brow, cheek, mandible and jaw movement, all radio controlled by four puppeteers with joysticks. The predator body was similar in



To meet the production’s on-set alien requirements, the A.I. build list included five animatronic alien heads, several nonarticulated stunt versions, and one hydraulic insert attack head. A.I. technician David Brooke installs a drool tube into an animatronic alien head.



To absorb some of the weight of the head and suit, and enable him to do more creature-like, dynamic moves, Woodruff designed a bungee-assisted flying rig to use on set in specific shots. Woodruff, in the suit, tests the rig with A.I. team members Steve Koch, Yuri Everson and Seth Hays.

construction to the alien's — a one-piece foam rubber suit that zipped up the back. Hands, feet, and armor pieces went on separately. "We made separate armor pieces to give Ian more freedom of movement," noted Gillis. "The armor pieces would shift and move on his body instead of being locked down to the rubber."

Through this variety of alien and predator makeup and animatronic creations, A.I helped Anderson and Bruno achieve the goal of capturing most of the creature shots on the set, leaving relatively few visual effects shots for postproduction. It is the way Woodruff and Gillis like to work. "We all wanted to let the practical effects rule the day," Gillis stated. "Then, wherever the animatronics could not accomplish certain things — and we're the first to say that animatronics have limitations — they would go to CGI. We like that approach, not just because we are practitioners of practical effects, but because we think it is a great way to establish the look of a film. Once you have that, the CGI artists have something concrete to match to. It gives them a firm foundation."



In addition to floppy and hand-puppet face-huggers, A.I built an animatronic version capable of scuttling across the set floor on its eight spindly 'fingers.' Though the weight of the animatronic was on a long control arm, multiple points of movement in the radio-controlled digits and at the base created the impression that the creature was propelling itself across the floor, rather than being manipulated from off-camera. Mechanical designer Seth Hays tests the mechanized face-hugger.

Multiple vendors in London and Prague built upon that firm foundation to deliver 500 visual effects shots — among them, shots featuring computer animated aliens. The CG alien assignment went to The Moving Picture Company, which based its warrior model on a laser scan of the A.I suit and head. “It was a pretty straight-ahead modeling task,” said MPC visual effects supervisor Adam Valdez, “in that we were copying that design. But we spent a bit of time working out what this creature was made of. Without knowing that, we couldn’t animate him. The alien design is really fairly vague, in terms of what is a hard insect-like shell, what is a stringy, musculature feature, what is a tubular, mechanical surface. The alien is made up of all of these things, and they are all intertwined. So, to do the animation, we had to come up with custom rigging solutions for all of these various physical characteristics.”

One of the things wanted to bring to the alien character was a more dynamic style of movement, with the alien striking the broad, iconic poses seen in the *Alien Vs. Predator* comic books. Within that directive, however, MPC had to ensure that the creature’s dynamic actions would not reveal its underlying human anatomy. “The alien is one of the hardest characters to animate in CG because he was born as a man-in-a-suit,” Valdez commented. “When you put him through more active movements, such as leaping or scaling a wall or hanging upside down, it quickly starts to look like a guy in a suit. Trying to get these great iconic poses without seeing the human form underneath — elbows, arms, legs — was very difficult. We had to animate the alien in a way that would make it look cool and exciting and scary, without revealing its man-in-a-suit reality, and without blowing the illusion of this incredibly lethal monster.”

Lighting of the CG alien was also critical in maintaining the illusion, requiring as artful a touch as that used in lighting the suited, on-set aliens. “This is a character that has always been played in the shadows,” Valdez said. “In talking with Tom and Alec, we all agreed that just because we were doing a CG version, that didn’t mean we wanted to parade the alien around in all his glory, in broad daylight. We lit and composed all of our shots to make the alien look good — just like they would do to make Tom in the suit look good in the live-action.”



Finishing artist Tony Matijevich fits the skin onto the animatronic face-hugger.

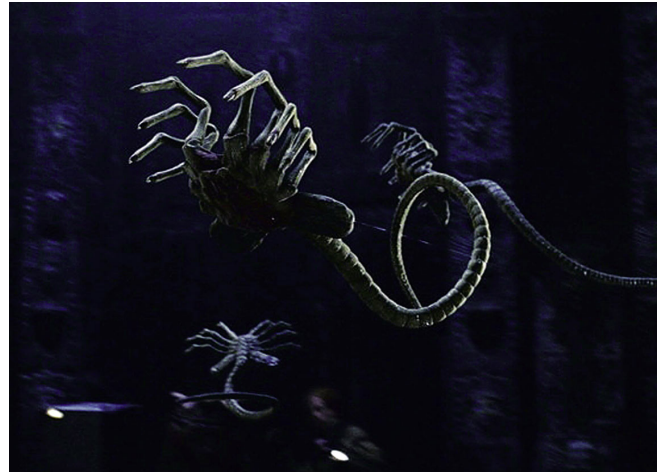
Matching the CG and practical creatures was never so critical as in the central fight scene between an alien and Scar, in which the action cuts back and forth between an animated alien and Woodruff in the suit. “There were shots where we cut straight from Tom Woodruff in the suit to a CG alien flying through the air,” explained MPC digital effects supervisor Ben Shepherd. “The CG alien would land on a stunt guy, and then we’d cut back to Tom rolling around on the floor. The biggest challenge was to make sure that our alien always cut really well with the practical alien — which, primarily, meant making it look really wet.”

Emulating the look of the slimy on-set alien required a combination of shaders and intricate lighting. High dynamic range images taken on the sets gave the digital artists a good foundation. “We would edit the HDRI and add extra light to it,” stated Shepherd, “or add bounce cards in 3D to give it more specularity. If we didn’t have HDRI, or the HDRI wasn’t quite right, we’d do the whole thing with synthetic speculars.”

Shaders applied to the high-resolution alien model created the creature’s metallic, wet and highly-reflective look. “We had one level of displacement to define all the fine cracks and wrinkles on the model. We had one level of reflection and specular displacement; and then we had the slime displacement. Another level of more dominant wet specular went on top of that.” Even when the wet look had been achieved perfectly in a still shot, it would all be lost once the alien made a fast move. “Motion blur totally annihilated all the highlights. We would have these beautiful stills of a wet and slimy alien; but as soon as he flew through the air, the motion blur would turn him into a blob of black, with no highlights, no wetness — and the highlights and wetness are what make this creature. We’d have to adjust the motion factor in RenderMan in those shots to keep the alien looking crisp and wet.”

Though much of this fight scene and others were shot on set with predator performers in suits, some of the more outrageous fight moves required a CG predator, also built by MPC. The predator digital double had not been in the original game plan; but it was added to MPC’s slate when production ran into difficulties trying to do wire work with the main predator performer. “Ian White was over seven feet tall,” said Adam Valdez, “and by the time he was suited up with all the latex rubber and armor, he weighed so much that it became very difficult to lift him on wires for some of the more dynamic fight moves. So we ended up building a fully CG version of Scar for a handful of shots. We scanned the suit and the mask separately, and then our texture team took it from there.”

The granddaddy of all fight scenes is a flashback depicting the history of the predator/alien ritual contest. MPC generated previz for the scene in preproduction, and used it as a guide in developing



In a slow-motion shot, multiple face-huggers spring from alien eggs and fly toward their human victims. The action required computer generated face-huggers, executed by Cinesite. Because the CG face-huggers would cut directly with the practical versions, exact matching was critical. Cinesite shot reference photographs of the A.I face-hugger, and used them as the basis for texturing its digital version. Even more detail was required, however, because of the scrutiny afforded by the slow-motion camera. Displacement maps created additional organic detail, while shaders emulated alien slime.

its final shots, some of which were entirely digital. The scene starts with an epic view of predator ships arriving in an ancient civilization. “This shot had CG spaceships,” said Valdez, “full CG city and pyramid environments, and a big matte painting showing jungle canopies out in the distance. We put in a CG crowd of city-dwellers for that shot, using the crowd system we developed for Troy.”

A second shot shows a predator slaying an alien, the dead creature’s body rolling down the pyramid steps. With the exception of a predator performer on a partial pyramid top set, all of the images in the shot were computer generated. The scene is followed by another epic shot revealing thousands upon thousands of aliens swarming up the side of the pyramid as three predators attempt to fight them off. “For that shot,” said Valdez, “we modified our crowd system to do crawling aliens swarming up this pyramid shape. All of the aliens in that shot, even the ones at the top, are computer generated.” The three predators were performers in suits, shot on the pyramid set as they mimed fighting aliens. MPC animated CG aliens to connect with the movements of the stunt predators.

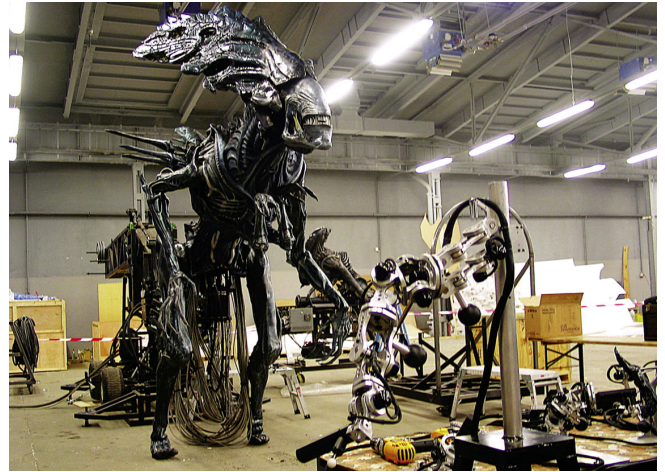


A.I built a full-size hydraulic queen for interactive shots with actors on set. To construct the creature’s eight-foot-long head, A.I sculpted over the original full-size head from Aliens – borrowed from collector Bob Burns – and cast a more lightweight version out of fiberglass. Finishing artist Matthew Killen adjusts the teeth on the alien queen head.

The crowd system that produced the alien swarms had to be modified from its original configuration for Troy. “The soldier that it was designed for in Troy was much simpler than the alien,” Ben Shepherd explained. “Even though the alien is essentially a black thing with highlights, it ended up being quite a complex shader setup, and we had to do an interpretation of that alien shader for the crowd. In the pyramid shot, we started off with hero CG aliens with full geometry in the foreground; and then, as the camera pulled back, we had to go to approximation geometry, with an approximation shader. It was quite tricky to get the CG heroes and the lower-rez aliens to match up. In our favor, the crowd quickly overtakes the hero alien and covers him up. But up to that point, there were two levels of aliens with two different shaders, side by side.” MPC incorporated 2D aliens on cards to fill the shot’s distant background.

In addition to its CG alien warriors, MPC delivered a computer animated alien queen — specifically, for a topside battle at the end of the movie, in which the queen is revealed head-to-toe, full-frame, out in the open, in an overcast daylight environment. “You see the queen out of the shadows,” said Valdez, “running around and doing major actions. We were able to get away with quite a bit, because it was an action scene and she was moving really fast; but it still had to be a very high-resolution model, because she is so detailed.”

Digital artists devised different shader schemes for the queen — one for the creature in her pristine state, and two more for the bomb-and-battle-damaged queen. “The hardest thing with the battle-damaged queen was keeping her from looking like Lemon-curd Head,” noted Ben Shepherd. “She was supposed to be dark and sinister, but her coloring was almost bright yellow by the end of the film because of all the yellow alien blood on her. We had to extend the shader to cover all those extra levels of damage.” Another problem in achieving a sinister-looking queen was that the foggy on-set lighting environment tended to flatten her out when replicated in the virtual world. “If we lit her with the HDRI from the set, which was basically a fog bank, she didn’t look wet. So, the HDRI approach was all but discarded for these shots. It gave us a place to start, but we built up from there, using specular lights, bounce cards and reflection cards. In almost every shot, she is backlit, because that is how she looked best.” In story terms, the backlighting came from a parked Snow Cat with its headlights on. “The headlights created some rim lights on the queen and brought out her wetness — but we cheated it. No matter what angle you look at her from, the light is always pointing in the same direction. She is always 3/4-backlit, with rim lighting on the outside.”

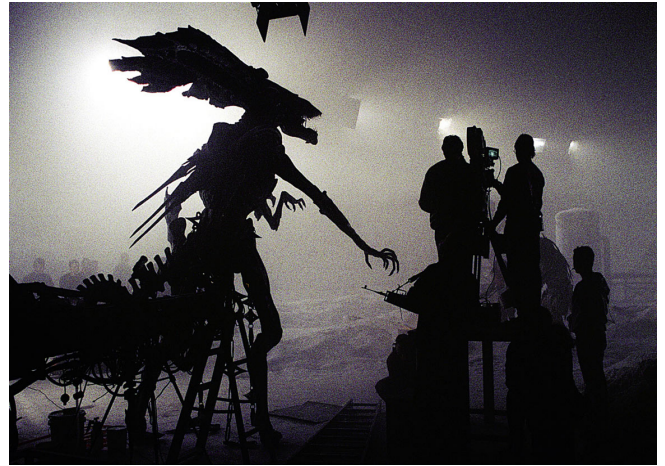


Body fabrication required scanning the 1/3-scale queen puppet, producing a scaled-up foam version from that scan, then sculpting, molding, casting and assembling separate full-scale pieces over a mechanical armature. The final full-scale queen measured 20 feet from the top of her head to the tip of her tail.

While MPC grappled with its slate of digital alien and queen shots, Double Negative was developing and improving upon past predator effects, such as the creature's invisibility cloaking and predator-vision. "The biggest challenge was to take established effects like the cloaking and predator-vision and bring them into modern times," asserted Double Negative 3D visual effects supervisor Mattias Lindahl. "Audiences will expect those effects to have evolved since the first movies; but they will also be disappointed if they look too far removed from the original effects."

In the previous *Predator* films, cloaking had been achieved by optically manipulating an element of a predator performer in a greenscreen suit, acting within a set environment. The optical process took a silhouette of the predator and placed sections of the background within that shape. Because the shape was concentrically scaled, several iterations of the predator's outline would be repeated, each iteration inside the last. The result was a prismatic lensing effect, a 'step and repeat' pattern. "This was and is an iconic, signature effect for the fans," commented Double Negative visual effects supervisor Richard Briscoe, "and one that we had to stay true to; but it felt very flat and two-dimensional. Our brief was to update the effect and give it more volume and mass."

The new cloaking effect started with shooting the costumed predator on the set — just to give the editorial department something to work with until final effects shots were delivered — then shooting a clean background plate, without the predator, and, finally, shooting the predator against a section of greenscreen. "That greenscreen plate gave us a predator element that we could isolate and place back into the shot," explained Briscoe, "while the clean plate gave us the background that would be seen — distorted — through him." Volumetric displacement of the background element, driven by luminance values of the filmed predator elements, produced the distortion effect. To give the effect a more organic feel, the images were broken up with fractal noise patterns or by offsetting individual red, green and blue channels. "We also blended back in varying degrees of our own, more



The full-scale alien queen was shot on a smoked stage set representing a mist-shrouded Antarctic ice field. A.I operators employed a motion control system called 'Overdrive' to program the animatronic creation and execute repeatable moves.



For some shots, the front section of the full-scale queen — head, arms and torso — was mounted onto a crane arm to allow it to be raised and lowered into frame. Crew members dress the crane-mounted queen with yellow alien 'blood.'

three-dimensional version of the ‘step and repeat,’ which was adjusted significantly depending on camera angle and the predator’s distance relative to camera and speed of movement.”

Most often, the cloaking was a 2D effect put together in Shake. In shots of the predator very close to camera, however, Briscoe and his crew determined that they needed to see distortions driven by the form of the hidden, off-camera side of the predator. In those instances, a 3D predator was matchmoved onto the photography, allowing Double Negative to re-create areas of the predator form that had not been photographed. 3D elements were also used for shots in which a predator de-cloaked. “3D animators created reveal mattes to allow the compositors to transition between the cloaked predator and the visible one,” observed Briscoe. “These mattes were created in Maya, by running various noise patterns through an animated edge that traveled across the surface of the matchmoved 3D predator. This gave the compositors an edge that had a real feeling of traveling over a three-dimensional form. The mattes were then time-shifted, frame-averaged, edge-detected, eaten into and generally messed around with in 2D.”

For its predator-vision shots, Double Negative again extrapolated from the look established in the original films. “Previously, they used a thermal camera to shoot the scenes and create the predator-vision look,” Briscoe said. “We did the same, but with a much more advanced thermal camera, which gave us a lot more detail. Then we regraded it and added CG elements.”

CG enhancement brought out objects that were not sufficiently clear in the thermal camera imagery. “There is a strong story point throughout the film about the predator guns that the humans are carrying,” Lindahl observed. “It was important to the director that those guns show up in the predator-vision. To make them stand out in the thermal footage, crew members had taken blow-dryers to the guns on the set to heat them up. But, in some of the thermal shots, the images were still quite blurred. So we replaced them with CG guns, grading them with a thermal shader in 3D to create the look of the thermal footage.”

Double Negative modeled and animated other predator weapons to effect more dynamic action than what could be achieved on set with the practical weapons. “We wanted the predator weapons to look more sophisticated than they had in the previous movies,” said Paul Anderson, “so we went with CG to augment the physical stuff. The spear in *Predator* and *Predator 2*, for instance, was big and chunky because they’d had to physically fold it up inside a tube. The deployment wasn’t very fast, either, because they’d had to physically do it — or they’d had to undercrank the camera, which was always obvious. The deployment of our spears is much faster and more lethal, and they look sharper and more elegant because they didn’t have to physically fold down into the handle.”



In the film’s action finale, a long-abandoned whaling station collapses into the cracking ice field, splintered by the force of a predator bomb. Though some partial whaling station sets were built full size, the entire collapse sequence was executed with a miniature – one of nine miniature sets constructed by Richard Van Den Bergh and his model crew. Each of the station’s buildings was made of prescored polystyrene to facilitate the collapse, triggered electronically on a motorized tabletop rig.

Special white casts of the practical weapons enabled Double Negative to get high-resolution scans. That data was taken into Maya, where the geometry was simplified. “We used in-house tools to get our displacement maps from the scans so we didn’t have to model all the fine detail on the weapons,” explained Lindahl. “Then we textured them, using photographs of the props. We also used HDRI that was taken on the set, which allowed us to reproject the environment on the geometry to create believable lighting. We added beauty lighting for glints to make the blades and spears look as sharp as possible on screen. The props on the set couldn’t have razor sharp edges and blades, obviously, because that would have been quite dangerous; so we had to enhance that.”

Although Cinesite delivered a number of shots for the film — including matte-painted establishing shots, set extensions, and miniature composites — the company’s creature contribution boiled down to a dozen CG face-hugger shots for a sequence in which multiple face-huggers leap out toward their victims in slow-motion. “We shot reference material of the practical face-huggers A.I had built,” related Cinesite 3D supervisor Ivor Middleton, who oversaw the project with 2D supervisor David Rey. “Our shots were going to directly cut with theirs, so we had to match what they had done. We got a hard-cast mold of A.I’s face-hugger, scanned that, then built our face-hugger in CySlice, creating a sub-divisional surface.”

Photographs of the practical face-hugger served as the basis for textures on the CG version; but, because the CG face-hugger would be seen in slow-motion, the digital team added considerably more detail, using displacement maps to create organic textures — and, of course, the always-present alien slime. “They had slimed up the practicals quite a bit,” noted Middleton, “and that is really what gave the hugger its look — the wetness and how that wetness played in the light. We took a lot of reference of the lighting they had on the set, and re-created that with shaders and texturing.” The slow-motion aspect of the shots also complicated the animation. “We had to do quite a lot of work between us and editorial to determine the speed at which it should be moving and the correct pacing.” Cinesite also removed wires and rigs connected to the practical face-huggers for in-camera shots that intercut with theirs in the scene.



In a climactic topside battle between the alien queen and the predator, the queen is revealed head-to-toe, full-frame. MPC modeled, animated and integrated a highly detailed, high-resolution CG queen into live-action plates filmed on a stage set. One of the challenges of the sequence was retaining the queen’s glistening wet highlights – a key to the look of all the alien creatures – within the flat, overcast lighting of the live photography. MPC solved the problem by backlighting the queen in every shot, regardless of the on-set lighting sources. Shaders gave the queen her battle-damaged, bloodied appearance.

As *Alien Vs. Predator*'s originally planned 300 effects shots grew to 500 during postproduction, John Bruno assigned shots to two additional vendors, one of them a local company, UPP Prague, which had won an Emmy for its work on the television adaptation of *Dune*. After proving itself with some set extensions, wire removals and animatics, UPP Prague was trusted with one of the movie's signature effects sequences — a scene in which the interior walls of the subterranean pyramid reconfigure themselves, creating a new maze of chambers, entrances and exits. Established in the film as an event that takes place every ten minutes, the reconfiguration would be revealed most stunningly in this first scene. "UPP is a small company," said Bruno, "a very energetic group of guys who really wanted to give this pyramid reconfiguration sequence a shot — and their finished shots were spectacular. So we gave them even more shots, including some in the queen's chamber, where they added electricity, smoke, and fire effects." Production also turned to Framestore CFC for matte paintings, explosion and fire composites, rig removals, and CG extensions of the 2,000-foot-long ice tunnel, only a very short segment of which had been built for live-action.

With virtually every member of *Alien Vs. Predator*'s effects crew a die-hard *Alien* and *Predator* fan, there was a huge sense of self-imposed pressure to live up to the legacies of those watershed films. "The *Alien* franchise, in particular, has produced some great movies," Anderson asserted. "Horror movies don't get any better than *Alien*. Action movies don't get any better than *Aliens*. It was very exciting to be a part of that tradition. Every day, people would come to the set, excited. 'We're making an *Alien* movie! We're making a *Predator* movie!' But that elation would inevitably be followed by: 'Oh my God...we're making an *Alien* movie. We're making a *Predator* movie.' We put a lot of pressure on ourselves; but, hopefully, it's paid dividends."

No matter how *Alien Vs. Predator* ultimately fares in comparison to its predecessors, the movie may set new expectations for future creature-heavy productions. "All movies are being done faster," Anderson concluded. "Schedules that were unheard of five years ago are now the average span of post — and that post continues to shrink. No doubt, *Alien Vs. Predator* will be used as a stick with which to beat other unfortunate filmmakers — because we did it in a very short period of time, and the movie still looks great. In the future, studios will be able to say: 'Look! They did that movie really fast, and they're English! You can do better than that. Do it faster!'"

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Hero predator 'Scar' – played by former basketball player Ian White – is impaled by the alien queen's deadly tail. The queen in the shot was MPC's computer generated model, but the tail was an A.I practical effect worn by the performer. MPC digitally painted out the tail tip at the beginning of the shot, then revealed it frame by frame in the final composite to make it look as if it was emerging from the predator's chest.

Something Wicked This Way Comes

ARTICLE BY JOE FORDHAM

From the opening moments of *Harry Potter and the Prisoner of Azkaban* — the third in Warner Brothers' ongoing adaptations of J.K. Rowling's fantasy novels — it is clear that something is up with *Harry Potter*. The once cherubic wizard-in-training is now a truculent teen, followed by a documentary-style handheld camera as he suffers the mundane indignities of his 'Muggle' home and family, then slouches off for his third year at Hogwarts School of Witchcraft and Wizardry.

Something Wicked This Way Comes

ARTICLE BY JOE FORDHAM



Teen angst causes Harry Potter (Daniel Radcliffe) to lash out as only a young wizard-in-training can, inflating his obnoxious Aunt Marge (Pam Ferris) and causing chaos in the opening scene of *Harry Potter and the Prisoner of Azkaban* – the third film based on J.K. Rowling's novels. Guided by director Alfonso Cuarón, the film was more contemporary in style than previous series' entries, filled with exotic creatures conjured by a panoply of effects artists led by visual effects supervisors Roger Guyett and Tim Burke. Marge's inflation, achieved practically on set, was digitally aided by The Moving Picture Company, which removed wire rigs supporting the actress through an opening in the ceiling.

The film introduces a presumptive new villain — discredited wizard Sirius Black (Gary Oldman), recently escaped from Azkaban prison and apparently intent upon murdering Harry (Daniel Radcliffe). Harry, meanwhile, crosses paths with Azkaban’s spectral security force — dementors — and encounters an array of strange new creatures that challenge his maturing talents.

Darker, edgier and more contemporary in style than its predecessors, the movie — directed by Alfonso Cuarón — reunited cast and crew in familiar surroundings at Leavesden Studios, which had played host to four years of Potter production. On standby at the studio were cavernous Hogwarts interiors, bluescreen stages and workshops housing the art department, John Richardson’s physical effects department and Nick Dudman’s prosthetic and animatronic studio.

New to the team, Cuarón brought with him a distinctive history of past projects as diverse as *A Little Princess* and *Y Tu Mamá También*. “One of the issues with a franchise like *Harry Potter*,” commented visual effects supervisor Roger Guyett, “is that, visually, the movies could lose momentum. The studio was very interested in giving this film a different look. When I first met Alfonso in Los Angeles, in summer 2002, I knew he had a background in cinematography, so I brought along art reference to help our conversation. Albrecht Dürer, for example, was a 16th-century German artist who had done etchings of griffins, similar to our ‘hippogriff.’ Images by William Blake and Gustave Doré were helpful reference for the dementors. It was an interesting way to get to know Alfonso, and I found him to be an extremely visual man.”

Guyett joined forces with Tim Burke, a fellow Potter veteran who initiated production at Leavesden and would share an equal role supervising the overall visual effects assignment. While production designer Stuart Craig and director of photography Michael Seresin fashioned designs and scouted locations, Burke and Guyett embarked on previsualization to lay the groundwork for Cuarón’s visual style. Previz allowed effects producers Theresa Corrao and Emma Norton to assemble reference material for prospective effects facilities — including Industrial Light & Magic, The Moving Picture Company, Cinesite, Framestore CFC and Double Negative — as production rolled toward a February 2003 start date.

Opening the film is a Moving Picture Company shot that descends over Privet Drive into a live-action plate of *Harry Potter* in his bedroom, practicing wand illumination. The shot employed a 1/4-scale miniature of the suburban residential environment, built for the previous movie under the supervision of José Granell, now operating the miniature effects facility at Shepperton Studios. Model unit director of photography Nigel Stone photographed the miniature as a multiple-pass Milo



Alfonso Cuarón lends a hand to creature and makeup effects designer Nick Dudman during preparation for the final stage of Aunt Marge’s inflation. Dudman’s team produced three prosthetic makeup stages for Pam Ferris, in addition to body suits featuring lycra understructures and inflating bladders. Puppeteers created the inflation effect using an off-camera pneumatic control system activated by keyboard control. Physical effects supervisors John Richardson and Stephen Hamilton used a combination of rigs to float Ferris about the set, including wire harnesses that allowed Marge to spin and roll, and a form-fitting fiberglass shell supported from below by a pole-arm rig mounted on a crane.

motion control move executed by The Visual Effects Company, a new facility raised from Mill Film's former film division. MPC tracked the miniature into the live-action set, then added 3D titles and a digitally-enhanced 'Lumos' wand effect.

The wand effects — a combination of practical effects and digital animation — were among the subtle revisions brought to the new movie. "Alfonso wanted an organic, optical-looking effect that he could believe was done in-camera," stated Burke, "with a practical light source illuminating the wand tip. Michael Seresin experimented with various bulbs that emitted different types of light and lens flare, then devised a way for Harry to hold his wand while a Chinese lantern on a boom created a very soft glow."

John Richardson, who shared physical effects supervisor duties on Azkaban with Stephen Hamilton, created self-illuminating wand props. "A lot of wand effects were in front of children's faces," said Richardson, "so we had to be careful not to use a bulb that could explode. LEDs were cool-burning and incredibly bright, but very directional and only worked looking straight down the end of the wand. We ended up using tiny pea bulbs to get the right color temperature and balance." Wands were powered by batteries hidden in the wand handle, or were attached to battery belts via wires fed through the performer's sleeve.

For a later scene in which Harry prowls darkened Hogwarts corridors illuminated only by his wand, Seresin exposed for the practical wand effect, with minimal fill from the Chinese lantern. Cinesite digitally removed the lantern wherever it was seen in shot and developed a range of wand effects to enhance in-camera illumination. "We came up with 37 Lumos designs in Shake," noted Cinesite visual effects supervisor Simon Stanley-Clamp. "The final effect was a pulsing colored hoop that emanated from the wand tip. We enhanced the practical starburst effect, and added a blue glow around it, with animated hoops tracked back to the light source. The plates were illuminated to the end of the hall, so we crushed the brightness down and animated garbage mattes that only revealed the areas where Harry held the wand."

For the opening of the film, MPC replicated the Cinesite Lumos effect and provided digital enhancements for a subsequent sequence featuring Harry's obnoxious Aunt Marge (Pam Ferris), whom he magically inflates to dirigible proportions. Nick Dudman's team designed custom body suits for Ferris featuring lycra understructures and inflating bladders. The prosthetic team built two expanding suits, a fully expanded non-inflating version and a version for a stunt performer who enacted wider flying shots. "We took Pam Ferris through three prosthetic stages and overlapped them," said Dudman, "so it was not apparent when we changed from one suit to another." The makeup took three and a half hours to apply. After Ferris waddled onto set, puppeteers connected her to an off-camera pneumatic control system and activated inflation by keyboard control. "We could play her like a piano. She had 12 bladders in each hand, for example, so we could blow up the tip of a finger, the center of a finger, the bottom of a finger, the palm, the back of the hand, the wrist, in any order we chose."

MPC provided digital fixes and rig removal where John Richardson's team and wire-rig specialists raised Aunt Marge aloft utilizing a combination of flying rigs. Ferris wore a custom harness that extruded from her back or sides; an overhead wire rig allowed her to spin and roll. As the character floated out of the conservatory, Ferris lay in a form-fitting fiberglass shell supported from below by a pole-arm rig mounted on a crane. To enhance Marge's buoyancy, MPC subtly re-animated her motion, adjusting her position in 2D.

The startled woman drifts out into the garden, shot on a soundstage set with a painted cyclorama sky. MPC digitally replaced the sky with photographic elements of shrubbery and miniature background rooftops, and graded the scene to a dusk-time look. Angles of Marge sailing skyward, leaving her relatives horrified below, were also shot on the garden set. MPC tracked the shot and supplied data to duplicate camera motion on the miniature suburban set. "We tracked in the surrounding gardens," explained MPC supervisor Paddy Eason. "We added a live-action cat on a fence and a barking Golden Retriever next door. We composited Marge into the foreground as a bluescreen element, then modeled and animated a CG Marge as a tiny speck bobbing in the evening sky as Harry exits Privet Drive."

Harry begins his journey to Hogwarts by boarding a 'Knight Bus' — Rowling's whimsical take on London's nocturnal public transport system, re-imagined as a purple triple-decker complete with beds for snoozing wizards. The physical effects department constructed a practical Knight Bus, cannibalized from three vintage RT-class London buses. For extra power and maneuverability, Richardson built the Knight Bus on the chassis of a modern single-decker bus, trimmed to RT width. Richardson's team resealed the driver's cab, configured brakes and steering to work with the single-decker's engine in the center of the vehicle, and added ballast. "We mounted a four-ton weight basket as low as possible in the chassis," said Richardson. "We then fitted our RT body to that, built a new middle deck, cut the top deck off another double-decker, and seated that on top."



Harry heads back to wizard school via a purple triple-decker 'Knight Bus,' a nocturnal wizard transport that hurtles pell-mell through the streets. Physical effects engineered a 22-foot-tall triple-decker, customized from London Transport double-deckers, which stunt performers drove through London locations. Roger Guyett oversaw visual effects of the bus traveling at hyperspeed through traffic. Double Negative sped up the live footage, added motion blur, and created interior window composites. For a tight squeeze between two oncoming double-deckers, Double Negative computer-generated a malleable model of the Knight Bus, with interactive lighting.

Stunt coordinator Greg Powell put the practical bus through its paces on the streets of London. The shoot was complicated by the fact that the 22-foot-tall vehicle could not commute between locations. “All bridges in London are a maximum 14 feet high,” noted Richardson. “So, every time we wanted to take the bus to a new location, we had to take it apart using two low-loaders, three trucks, a huge crane and a vast crew of people.” Effects crews arrived on location one night before shooting, assembled the Knight Bus overnight, then returned for shooting the next evening. The crew repeated the exercise on eight nights spread across eight weeks in the shooting schedule.

For interior shots of occupants rattled by the bus ride, Richardson constructed a motion-controlled gimbal, three decks tall, dressed with a chandelier dangling through two upper decks of cutaway mezzanine floors. Shot on a soundstage surrounded by bluescreen, the rig rocked side to side and back to front, causing wizard beds to slide about on hidden tracks.

To provide background plates for window exteriors, Roger Guyett collaborated with Joe Dunton Cameras to shoot 360-degree views traveling through London streets. “I’d read about cyclorama camera systems that were used in old ride footage,” said Guyett. “They traveled down a road, shooting in all directions simultaneously, creating moving 360-degree views. I thought it would be a great way to give Alfonso complete freedom for interior bus shots, without being locked into predetermined plates.” JDC constructed a 15-camera rig that captured a moving dome of footage and allowed Guyett to create lighting effects on the bluescreen stage. “We set up an Avid suite to go through all the footage of our traveling 360 view. We used projectors on set, connected to our motion control system, and projected footage into the interior of the bus. That gave us interactive lighting, while the lighting guys added other lighting effects, reacting to our



Dementors – the much-feared security force of Azkaban wizard prison – gather over Hogwarts, searching for escaped convicted murderer Sirius Black. Cinesite miniature effects supervisor José Granell oversaw revamping of the existing 1/24-scale Hogwarts miniature and provided elements for visual effects vendors, including Industrial Light & Magic. ILM generated the dementors as CG-animated figures – keyframed skeletons mapped with digital cloth simulations representing the characters’ flowing, tattered robes. Artists created organic, spectral motion by applying simulated wind forces, inverting gravity, running simulations backwards and hand-modeling cloth tendrils.



Using art department designs, Dudman conceptual artist Robert Bliss and animatronic model designer Kate Hill create a 1/3-scale maquette for the unclothed dementor skeletal form. Cast in silicone and detailed with a thin, fleshy membrane, the completed maquette guided ILM’s digital creature modeling team. Before committing to an all-CG approach for the creatures, the production investigated practical puppetry techniques. The Dudman team created 1/3-scale dementor rod puppets, clothed in loose flowing garments, filmed underwater. The puppets’ motion proved too unwieldy to orchestrate to precise

playback. We then used the background footage to composite into bluescreens outside the window.”

timings, but the tests produced valuable animation reference for the CG team at ILM.

Double Negative stitched together selected cyclorama plates to generate composite background tiles and created digital effects through the sequence. When the Knight Bus first screeches to a halt in front of Harry, Double Negative unveiled the towering vehicle with a rolling soft-edge wipe, from bottom to top. “The idea was that Muggles can’t see the bus,” said DNeg CG supervisor Richard Clarke. “It comes out of Muggle vision into Harry vision.” For scenes of the bus careening through the city, Double Negative tracked in practical and CG steam emanating from the radiator cap, added streaking effects and retimed background plates. “Roger photographed the bus traveling at normal speed, with surrounding traffic moving at one-third speed. We sped up the footage to bring the traffic up to normal speed, accelerating the bus like ‘Mr. Toad’s Wild Ride.’”

On Lambeth Bridge, the triple-decker almost collides with two double-deckers headed towards it, but at the last moment squeezes through a narrow gap between them. Double Negative created the exterior squeeze using a digital model built from reference photographs. “We didn’t know how the squeeze was going to work at first,” said Clarke, “so we went through quite a few polygonal and NURBS models, then subdivision surfaces, based on how the director wanted it to deform. Subdivision surfaces gave us the flexibility to redivide and put it back together in an organic fashion.”

The interior squeeze deformed both Harry and his environment — achieved by warping lattice models of the bus and boy, reprojected with photographic textures from the plate. “Modeling the interior from scratch would have meant texturing, setting up shaders and lighting to mimic something we already had,” explained DNeg visual effects supervisor Mark Michaels. “Instead, we used a 2D/3D process to create a complicated 3D warp. We modeled very simple geometry of Harry and all the objects in the bus and used high dynamic range lighting reference for the interaction of shadow and light, projected through the camera.”

Harry’s trip to Hogwarts takes on a darker tone during a train ride with his classmates. Double Negative set the mood in exterior shots, photographed in Scotland, adding rain and train smoke, and darkening the skies as the Hogwarts Express grinds ominously to a halt on a viaduct. Inside, train carriage windows freeze over — achieved with motion control passes, one clean and one dressed with a translucent lacquer to create ice effects, enhanced in the composite by ILM compositing sequence supervisor Pat Brennan. Harry and his friends are then terrified as a towering figure drifts into view — their first sighting of a dementor.

The eerily beautiful creation was realized as an all-CG character by Industrial Light & Magic, from a design by the art department and Nick Dudman’s maquette team. Initially, production investigated physical solutions to bringing the wafting, cloth-like specter to life. “Alfonso wanted to attempt to create the dementors as full-sized puppets filmed underwater,” stated Dudman. “We made up some very simple rod puppets at 1/3-scale, dressed them in fabric and put them in a water tank.” The production employed the services of puppeteer Basil Twist, who had featured underwater swirling fabric in his off-Broadway production, *Symphonie Fantastique*. “Basil Twist demonstrated moving fabric around on a stick and we shot some film tests with our dementor maquettes, blowing water

around underwater to create waves and movement. Every now and then, this produced some really wonderful effects; but, most of the time, it didn't, because it was impossible to control. There was no way we could make the movements match a live-action plate. It became obvious that the only logical way to do this was CG."

To guide the CG dementor project at ILM, Cuarón selected key moments from the puppetry tests that he felt conveyed the dementor's essential character. ILM's assignment was to replicate the otherworldly feel of the tests in organic characters expressed principally through cloth simulation. "The dementors were the chief bad guys of the film," commented ILM visual effects supervisor Bill George, "but they had no eyes, no face, nothing to express emotion. It all came down to body posture and the way the fabric moved. One of my goals was to get the cloth simulation guys — who usually strive to simulate reality — to be more creative in how they utilized their software, turning the model upside down, turning gravity off or running simulations backward."

To model the dementor, ILM referred to painted silicone maquettes detailed by Dudman's studio to represent the creature clothed and unclothed. The unclothed form depicted a truncated skeleton covered in a thin membrane of flesh, with claw-like hands, an eyeless skull with a cyclopean maw, and a dangling spine that trailed off like a rat's tail. "Our lead CG modeler, Michael Koper, built all of the skeletal detail," stated George. "Digital artist Tom Fejes then covered it in fabric, and we kept it very dark. Alfonso steered us toward keeping the dementors very mysterious and spectral." Models revealed hints of anatomy when animated wind sources pushed fabric into the rib cage, but the CG form was unmuscled, clothed in a single cloth-simulation mesh, detailed with only as much texture as one computer could render overnight.

The apparition in the train was the first dementor animated by ILM. "Steve Rawlins created animation of the skeleton coming down the corridor," related ILM animation director David Andrews. "Cloth sim lead Steve Sauers then moved a CG wind source coming up from underneath, blowing across the character to make the tendrils rise. We shaped the tendrils by hand to make them more dynamic, bringing them up in frame then letting them fall back down. It took that kind of frame-by-frame handcrafting on top of the simulation to create the emotional effects we needed."

The creature closes in on Harry and emits warping energy from its maw, draining the boy's soul.

"Alfonso wanted a very subdued effect," said George. "Our first soul-suck tests were way over the top. Part of my job was to learn the more organic, subtle look that Alfonso wanted." The final soul-draining effect employed a mix of particle animation, animated shapes with projected textures, and Inferno paint effects.

Dementors are seen periodically throughout the film, patrolling Hogwarts' grounds and skies in search of Sirius Black. The creatures make their most spectacular reappearance during a stormy



During a lesson in the care of magical creatures, Harry Potter meets a hippogriff – a winged creature with the head of a bird and the body and hindquarters of a horse –

Quidditch game. The airborne wizard tournament had been realized in previous Potter films by incorporating bluescreen and CG performers into largely sunlit 3D backgrounds. ILM returned to the arena for a briefer scene in howling wind and rain. Rather than generate 3D environments using volumetric CG clouds, ILM CG supervisor Kevin Sprout took a simpler approach. “This time, the real heroes of Quidditch were in the matte painting department led by Susumu Yukuhiro,” said Bill George. “We painted all those backgrounds in 2D and projected them in ‘2½D.’ We used real cloud textures with painted elements, put them on CG cards and ran camera moves through the cards. Stella Bogh then led the compositing effort. I was amazed how quickly we were able to create those shots. If we had gone the particle route, I think we’d still be working on it!”

named Buckbeak. Working closely with Tim Burke, Framestore CFC generated the hippogriff from art department concept drawings, horse and eagle nature reference and Dudman studio maquettes. The creature’s chimerical nature, conveying an animalistic sense of danger and majesty in flight, was created via keyframe animation, complex feather simulations, and a delicate blend of wind simulations and compositing that allowed digital artists to finesse fine details of lighting in a painterly fashion.

To choreograph the action, Guyett and George blocked the scene in previz, using the data to program motion control moves of performers riding broomstick motion-base rigs. John Richardson’s team blew wind and rain across bluescreen performers and applied wax, acrylics and Epsom salts to riders’ goggles to simulate freezing ice caused by the dementors’ reappearance. ILM also filmed physical elements to enhance the illusion of ice freezing up the virtual camera lens. “I’m a big believer in using practical elements wherever possible, particularly in foreground,” said George. “We spent a couple of days on stage shooting rain and ice hitting the lens. Our compositing supervisor, Dorne Huebler, used those elements throughout.”

Harry’s game is disrupted when he sees giant thunderheads taking on the shape of a snarling black dog — the ‘Grim’ — a harbinger of doom that has haunted him since his departure from Privet Drive, when it peered out at him from behind bushes. For that scene, MPC composited its computer generated Grim into a Cinesite 1/3-scale miniature park bench and shrubs. Originally, however, the creature had been conceived as a live canine performer. “We spent three months sticking ears on dogs,” recalled Nick Dudman. “Animal supervisor Gary Gero used a deerhound, a most beautiful animal, and had trained about five of them. We put fangs and ears on them, and the look was great. But the animal was not ferocious enough. Deerhounds are so sweet-natured, we could not make them appear fierce.” The production then considered animatronic and CG alternatives. “A couple of months before shooting, we sculpted a life-sized maquette and made an animatronic version for biting closeup shots.”

The animatronic was used briefly in one closeup, during a sequence with Harry’s friend Ron Weasley (Rupert Grint). All other Grim shots were generated digitally at MPC, which revised the original maquette design. Revisions included shortening the Grim’s legs and changing the size of the creature’s head. “Modeling the Grim was hard,” remarked MPC CG supervisor Simon Clutterbuck. “The maquette was quite a stylistic sculpt, anatomically — so we couldn’t build from that and expect it to be animatable. We ended up modeling five turntables — from really furry and matted to a dog with no fur at all — and Alfonso picked the one he liked.”

Fur played an important role in MPC’s creature pipeline, requiring development of new in-house software, named ‘Delilah’ — after the biblical legend of Samson and Delilah — which enabled artists

to generate and groom fur in real time using a Maya deformer toolset, while a variety of dynamic nodes could be programmed to inherit fur motion from the animated creature, before rendering in RenderMan. Delilah also allowed the Grim's complex matted pelt to be retooled for each modeling revision. "The Grim was made up of 12 different fur descriptions," explained Simon Clutterbuck. "When TDs dialed up animation, Delilah built the latest fur descriptions. We then propagated those descriptions through the pipeline."

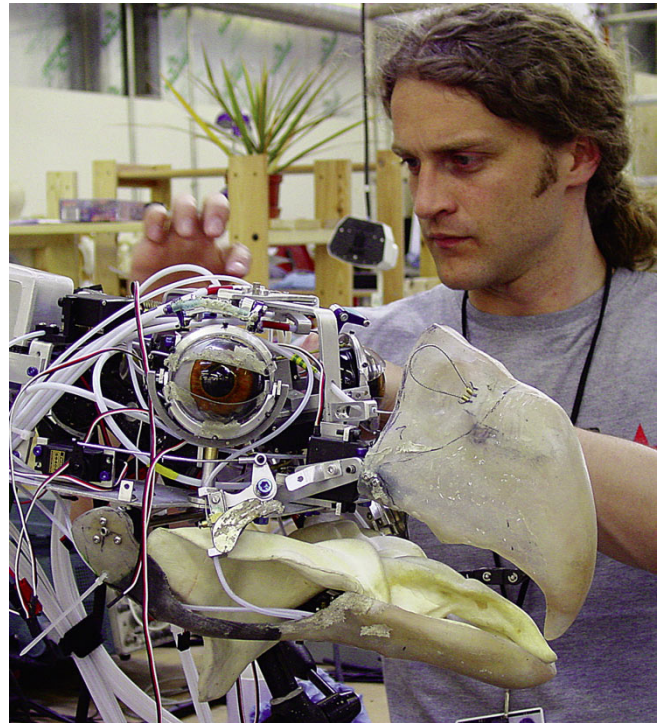
Another fantasy creature makes its appearance when Hogwarts' new 'Care of Magical Creatures' teacher, Rubeus Hagrid (Robbie Coltrane), introduces his students to a hippogriff named 'Buckbeak' — a winged griffin with the body and hindquarters of a horse. Eagle and horse reference served as early hippogriff motion studies, but Buckbeak's design relied most heavily on artistic interpretation. "A hippogriff is an offshoot of the ancient Greek mythological idea of chopping up animals and sticking different parts together," stated Nick Dudman. "The logic was insane, and we had to tread a very fine line between cartoon and real life. Chris Fitzgerald did a great job sculpting the maquette from Dermot Power's design. It then became a case of processing the design, scaling it up and adding some 30,000 feathers."

Dudman's team created three full-scale animatronic hippogriffs for the film — standing, rearing and lying down. Key animatronic designer Val Jones-Mendoza created plumage using mainly chicken and goose feathers obtained from the food industry. Feathers were sterilized, sorted and bulk-dyed; then artists airbrushed each feather by hand. Larger feathers were obtained from preserved carcasses of deceased swans. For the largest primary wing feathers, Jones-Mendoza's team used vacuformed, flocked and airbrushed plastic feather shapes. Feathers were hand-glued to a Powernet jacket, tailored to the animatronic's skin, stretched over internal mechanisms and then fastened with velcro and snap fittings. Primary feathers were rigged to cables and mechanized to splay as wings opened and unfolded.

Concurrent to the development of the animatronics, Tim Burke and Framestore CFC developed a digital



Harry and Buckbeak take to the air in a lyrical flying sequence as wizard and hippogriff swoop over Hogwarts castle. Framestore CFC generated the shot from aerial stills projected onto 3D geometry with matte-painted terrain, CG water and matte-painted skies layered behind CG hippogriff and boy and the 1/24-scale Hogwarts miniature.



Animatronic model designer Matt Denton attends to a mechanical hippogriff head in Nick Dudman's studio. Full-scale mechanized hippogriffs were used only sparingly in

version of the hippogriff intended for ambulatory and flying scenes, creating CG motion studies from production art and creature shop creations. “Putting a bird’s head on top of a horse’s body brought up issues of bone structure and anatomy,” said F/CFC animation supervisor Michael Eames. “Birds are extremely light, and their bone structure is designed for flight. We took some license to make the head move in a birdlike fashion, because a creature of that size probably wouldn’t be able to move that fast. More importantly, Alfonso wanted Buckbeak to be like a sloppy teenager — animalistic, with a slightly wild side. But when Buckbeak took to the air, he became a graceful and majestic beast that was completely in control of his own direction and power.”

The lying-down animatronic was the first version to be filmed in Glencoe, Scotland, which served as location for all exteriors surrounding Hogwarts. The creature had a computer-controlled head and an ‘aquatronic’ body — an animatronic control system driven by water pressure — manipulated by ten operators that hid behind a wall outside Hagrid’s hut, where the hippogriff was tethered. The animatronic was mounted on rails, allowing it to slide back through a gap in the wall to be stored inside a tent overnight. The highland climate, however, conspired against the shoot. “It was a nightmare,” asserted Dudman. “When it wasn’t raining, it was hailing. When it wasn’t hailing, it was snowing. The side of the hillside became a river of mud. The production kept putting down more turf, which got washed out. Poor Val Jones had to keep the feathers clean, with mud splashed everywhere. It was awful.”

Though all mobile shots of the creature were intended for computer animation, additional animatronic hippogriffs were built for a scene in which Hagrid introduces Buckbeak in a nearby paddock. Dudman’s team created a full-scale static lighting model to assist with shots of Buckbeak standing, then mechanized the creature so that it appeared to be attentive to Hagrid’s introduction. Animatronic designer Matt Denton reused head mechanisms from the lying-down hippogriff and packed linear-actuated motors into the creature’s belly to add body motion. The model could spread its wings, move its head and beak, and blink. The right

the final cut, but served as the basis for a motion base developed by Framestore CFC for bluescreen closeups of hippogriff riders.



Quidditch – an airborne tournament in which wizards mount broomsticks to dodge and bag flying projectiles – had been realized in previous Potter films by compositing bluescreen and CG performers over largely sunlit backgrounds. ILM returned to the arena for a sequence set in howling wind and rain, in which the players were frequently lost in storm clouds, hundreds of feet above the field. Artists generated foreground elements in 3D. Backgrounds featured 2D matte paintings of clouds fashioned from real and painted elements projected onto CG cards, with 3D camera moves plotted through the cards.



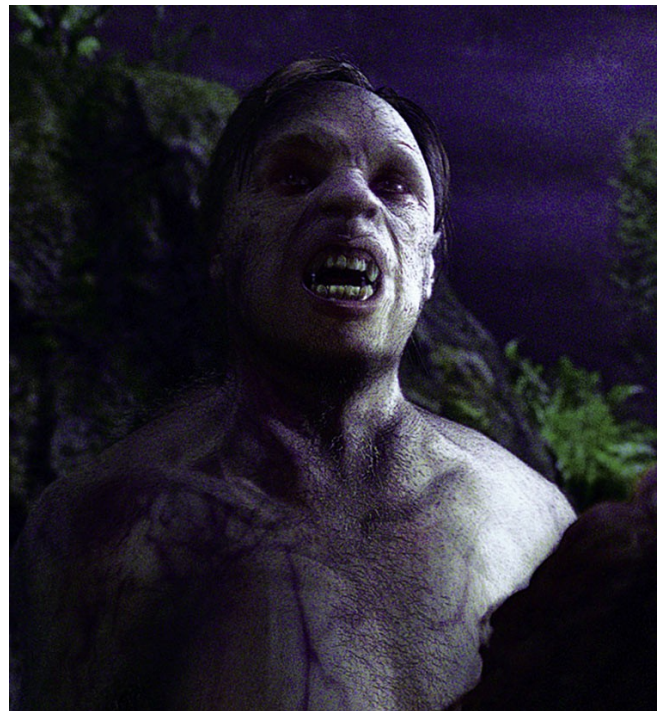
Hogwarts is seen in a variety of weather conditions through the film. Cinesite handled castle exteriors with elaborate camera moves, including a seasonal transition scene that followed Harry Potter’s owl, Hedwig, flying through an autumnal valley to Hogwarts in winter, where Harry is seen peering out from a high window. The shot featured a live owl, filmed against bluescreen, composited

foreleg and left hind leg could move, allowing the creature to shift its weight and curl its claws.

Ultimately, however, the animatronic hippogriffs appeared in only two shots, lying down in Hagrid's pumpkin patch. To capture the creature's mobile and interactive nature, Tim Burke and Framestore CFC previsualized all hippogriff scenes, and F/CFC visual effects supervisor Karl Mooney and Michael Eames accompanied Burke on the paddock shoot, referencing the previz.

Much of the CG hippogriff's development was devoted to creating highly realistic feathers capable of interacting with characters and wind turbulence. "A rough surface with texture map did not give us the detail we needed," said F/CFC CG supervisor David Lomax, "so we modeled every feather." Eight months of feather research and development began with the deconstruction of a single feather. "The central rib is called the 'rachis.' It has soft filament-like barbs growing out of it, which we represented as pieces of geometry. In-between the barbs, real feathers have 'barbules' — little velcro-like hooks that hold the barbs together. We modeled and used those depending on how close we were to camera."

into a scenic matte painting, which then transitioned to a snowy miniature with 1/10-scale clock tower nested into the 1/24-scale Hogwarts structure, tracking through 3D snow into a live element of Daniel Radcliffe at the window. The action was filmed on a soundstage with a partial prop tree, backed by bluescreen, for daylight scenes. MPC created a digital matte painting to surround the environment and modeled the Whomping Willow with several million procedurally generated leaves. Shots of the children being tossed about by the irascible tree were filmed in a bluescreen environment with actors riding a physical effects seesaw rig. Wide shots utilized digital doubles.



Hogwarts professor Remus Lupin (David Thewlis) reveals his lycanthropic nature by the light of a full moon in a climactic confrontation with Harry and his friends. Nick Dudman's studio generated a two-stage prosthetic makeup for Thewlis, extended by animatronic portions of Lupin's anatomy adopting canine form. In postproduction, MPC digitally modeled Thewlis' upper body and face and animated the painful transformation.

Some 16,500 feathers — with 6.7 million individual barbs — were applied to the CG hippogriff's skin, which was driven by a proprietary muscle system developed for Maya to effect dynamic jiggle in the skin. Wing motion posed complex muscle/feather interactions. "We wanted a fully opening and closing wing without any cheating," said Lomax. "Felix Balbas, our character rigging supervisor, came up with a way of ensuring that primary and secondary wing feathers didn't intersect as the wings went from fully open to fully closed." The rig prevented intersections in flattened primary feathers. After feather shaping, a 'splat' program resolved intersections and compressed feathers against one another in the closed wing. Wing feathers were also scalable. "A 21-foot wingspan just didn't look magnificent enough, so we settled on a 28-foot open wing — but the closed wing extended too far beyond the hippogriff's back, so we scaled the feathers down as the wings closed."



Digital artists used slide controllers to extrude Lupin's facial features, digitally replaced the actor's hair with a fur simulation, animated hair to spread and grow as the beast took shape, and employed shaders to change skin from pink to blue.

Tim Burke oversaw shots of Harry climbing onto Buckbeak's back and launching into the sky. Daniel Radcliffe was filmed against bluescreen, seated on an 'M-Rig' — a custom motion-base that Framestore CFC originally developed for the television miniseries *Dinotopia*. Hippogriff motion rig supervisor Guy Hudson refined the M-Rig for Azkaban to provide a flexible point of contact on an articulated hippogriff form, similar to a bucking bronco. "The M-Rig was essentially a flight simulator," said Karl Mooney. "It had three pistons on a revolving 360-degree base. On top of that, we mounted a sitting rig adapted from castings of Nick Dudman's full-sized hippogriff. We made the base-color gray to avoid bluescreen spill, without any feathers because we envisioned problems blending them with our CG plumage. Specialist animatronics engineer David Dunsterville, Guy and the M-Rig team designed mechanics to mimic our animation."

Framestore CFC fed Maya animation into the M-Rig, allowing Cuarón freedom to preview moves and create changes on site. Burke and The Visual Effects Company interlocked hippogriff animation with camera moves using a motion control system and a hulking Cyclops camera rig that rode up and down a 60-foot-long track. "The Cyclops gave us stability and reach in high-speed moves," remarked motion control operator Jay Mallett. "Motion control supervisor Chris Shaw used our Rig-Chase software to program moves from previz. We then performed a rough composite to the previz background. If Alfonso didn't like the way a shot was playing, he might suggest a different angle. We would reposition the rig, give that information to Chris, and he'd re-jig the move, then throw it back to me. Some of our moves weren't achievable at live-action speeds, so we applied varispeed effects, shooting slower at first, then ramping up at a specific cue point to achieve the actors' closeup reactions at live-action speed."

Hippogriff previz also provided guidelines for Roger Guyett, who supervised aerial background photography in Scotland. The sequence included swooping wide-angle views over a Scottish loch and a low-level pass over the water surface as Buckbeak playfully dips in a claw. A small catamaran camera-boat shot practical interactive splash effects on the loch, utilizing a lever with metal spikes, which Framestore CFC digitally removed. For wider views, F/CFC generated CG ripples and white water to create interaction between the hippogriff and the water surface.

To integrate hippogriff and riders into the environment, F/CFC developed a multi-component imaging system to break down render passes. “Rather than writing traditional beauty and shadow passes for RenderMan,” explained David Lomax, “Andy Kind, our lighting supervisor, constructed shaders to output translucency, occlusion, lighting, form and environment passes — breaking each render into 54 components — which we then reconstructed in Shake.”

To manage image components, senior compositor Areito Echevarria developed ‘Genie’ — a Shake network interface that allowed artists intuitive image control. “We could work like a painter,” commented Karl Mooney, “introducing creative lighting changes in the composite. In the paddock, for example, Alfonso wanted the scene lit with strong shadows; so we added highlights and shadows, illuminating the perimeter wall and bringing a consistency across all the plates. That also meant we had to relight the hippogriff, bringing out highlights in the beak and eye.”

Harry’s flight, and later scenes with riders on Buckbeak’s back, featured swooping shots that soared closer and more dynamically around the Hogwarts towers than had been seen in the previous two films. “Alfonso asked us to play with the flying sequences,” remarked Michael Eames. “The shots over Hogwarts incorporated ideas from the original previz. We developed those and came up with many versions. We experimented with timings, and then the animation drove camera moves over the Hogwarts miniature.”

Only 20 percent of that 1/24-scale miniature remained intact from the first Potter film. “There had been additions and refurbishments on each film,” commented José Granell. “We upgraded details, textures and painting to enable us to get closer and do more with the miniature. The back side of Hogwarts had additional landscaping and architecture, including a new courtyard, a hospital wing and a wooden bridge.” New structures were built with plaster and timber, rather than the Fastcast resins utilized in the original model, which better accepted paints and the heat from studio lamps.



Lupin’s final transformation, backlit by moonlight, revealed internal anatomy and a layer of veins. Technical directors built secondary muscle animation on top of the primary character performance, adding rippling tendons and animated drool. MPC also digitally enhanced the nocturnal setting. The production shot nighttime hilltop scenes on a soundstage set backed by a printed cyclorama and infused with practical mist effects. MPC corrected continuity in the mist, added a digital full moon, and occasionally replaced the on-set backing with a CG environment created from photographic scenic materials, matte-painted sky and digital vegetation.

Granel's team also rigged water jets around the shooting stage and wetted down the miniature before shooting to bring out masonry detail.

The 25-foot-tall miniature was surrounded by a 44-foot-tall greenscreen, with black velvet drapes swung in for beauty, key and fill-light passes. Smoke passes enhanced aerial perspective, and a fiber-optic network provided interior light sources. Cinesite assembled the majority of the Hogwarts exterior composites with exotic camera moves. Tim Burke oversaw a scenic shoot of Scottish landscapes, Cinesite tracked miniature elements into the landscapes, and created a grittier and more textured look than in previous films.

One notable change to the wizard academy was the positioning of the Whomping Willow, an ancient tree that comes irascibly to life when disturbed. "The Whomping Willow was in the castle courtyard in the first two films," explained MPC CG supervisor Peter Muyzers. "In Azkaban, it's near the dark forest, perched on an outcrop overlooking the lake. It was a visually more interesting environment, and the tree took on some distinctly different behavior." For live-action scenes around the tree, production constructed a full-scale set piece. Other shots required a digital version, fashioned by MPC from maquette scans, with several million procedurally generated leaves animated through the company's Cantilever dynamic system.

The virtual tree has a star turn in a scene in which the branches come alive to attack Harry and Hermione (Emma Watson). Large portions of the action were filmed in a bluescreen environment, with performers whirled around on a rotating seesaw rig built by John Richardson's team. Closeups of Hermione raking through the branches were accomplished with Watson strapped to the spinning steel-framed rig, filmed at 50 frames per second. MPC then animated branches to slap through frame as Watson flinched. MPC also built detailed digital doubles for both Hermione and Harry, used sparingly in distant shots.

All daylight action surrounding the willow was shot on the Leavesden soundstage backed by bluescreen. Independent matte painting contractor Charles Darby generated a digital matte painting of the view beyond the set. MPC sampled the same source material and generated a digital environment, which they composited into scenes. For nocturnal action, the production created a printed cyclorama backdrop from Darby's painting, which MPC enhanced. "The cyclorama created a really nice, stylized look," commented Paddy Eason, "but it was not consistent from shot to shot. We added the full moon, removed or added stripes of smoke, and sometimes replaced the entire backing to correct parallax between the background and the set."



Generated digitally by MPC, the Grim – a mysterious canine harbinger of doom – stalks Harry Potter through the film and makes an appearance in the hilltop fight. Early concepts for the creature included prosthetic applications on oversized canine performers, but the ferocity and unnaturally large size of the beast dictated a digital approach. MPC modeled versions of the Grim from a Nick Dudman studio maquette with variations in limb length and head size. The creature's matted pelt required development of fur simulation software, which enabled artists to generate and groom fur in real time and add dynamic effects.

The willow location serves as an arena for a conflict between Sirius Black, ‘Dark Arts’ professor Remus Lupin (David Thewlis) and the duplicitous Peter Pettigrew (Timothy Spall), who are revealed as animagi — shape-shifting humans with animal alter-egos. The first animagus makes its appearance in Sirius’ hideout, connected to the willow by a secret tunnel, where Scabbers — Weasley’s pet rat — transforms into Pettigrew in mid-leap. MPC animated Scabbers for the shot, thrusting the rodent through a splintering wall and transforming him into human form while airborne. To assist the change in scale, Tim Burke designed the shot with the rat leaping headlong into camera, enlarging as it filled frame. MPC devised a CG model with sliders controlling the transformation, changing the topology so that the rat’s fur unfolded into wardrobe and its head changed to Spall’s likeness. Spall performed his final transformed state wearing prosthetic ears, a bald cap and oversize rodent teeth sculpted by Dudman’s team.

Back at the willow, the appearance of the moon from behind a cloud triggers Lupin’s transformation into a pathetic, almost hairless, bipedal werewolf standing seven feet tall. Though the werewolf design featured nonhuman proportions, the filmmakers wanted to shoot as many shots as possible with a performer in a suit. “We maquetted the werewolf in its ideal form,” said Dudman, “then decided how we might compromise to accommodate a performer in a suit — but we didn’t compromise enough. By fighting to keep the design as near to the concept as possible, we created a suit that looked great but was a nightmare to perform in.”

Practical werewolf suits were manufactured to fit two creature performers — Belgian ballet dancer Marnix Van Der Broek and English kickboxing champion Spencer Wilding — cast for their tall, muscular but slender physiques. Performers wore skin-tight foam latex suits, and stood on custom stilts. The wearer’s ankle corresponded with the creature’s ankle; the creature’s foot extended an additional two feet to a support at the toe. When the performer threw his weight forward, he rose up on the stilts, taking his weight on the front of his shins. His head corresponded with hidden eyeholes in the creature’s neck, topped by an animatronic werewolf head — with radio-controlled eyes, brows, ears, jaw, tongue and snarl — attached to a load-supporting spine that distributed weight around the performer’s hips and shoulders.

After three months of rehearsal, the werewolf performers stepped out onto the rugged terrain of the hilltop set in the heat of a brutal summer. “We were fine until we got to the set,” recalled Dudman. “With the combination of claustrophobia and the position they were held in, the performers could do what they were asked to do, but not with grace. In retrospect, we pushed it further than we should have. It taught me that there is no good in saying, ‘Stick to the original concept.’ What I should have said at the beginning was, ‘Either this is purely CG, or we make compromises.’”



Werewolf and Grim face off in a ferocious confrontation. The sequence was originally designed to incorporate shots of a performer in an animatronic werewolf suit, but physical limitations of the suit on set resulted in an all-CG solution. MPC generated both characters digitally and developed creature muscle simulations using a ‘multi-weight enveloping’ technique – allowing animators to position characters in keyframe poses, then interpolate frames with muscle simulations derived from a library of pre-described deformations. Technical directors added fur dynamics, drool and disturbed clods of earth, then applied 2D camera moves with motion blur.

Apart from one quick shot, all of the werewolves in the film are CG — a decision that was not finalized until postproduction. As safety backup, Roger Guyett had shot clean plates without the on-set werewolf performers, allowing MPC to accommodate the revised effects strategy and integrate the CG creature it had been developing for wide, ambulatory shots. The digital werewolf required extensive muscle system research and development. “We implemented a paper on ‘multi-weight enveloping’ written by ILM,” revealed Simon Clutterbuck. “It put the werewolf through an exercise routine, moving him through 1,200 unique poses. The system learned the positions and we could tweak them if we weren’t happy with deformations. This built up a big library of poses. Animators could move the model around, and the system would fill the gaps, interpolating poses.”

Lupin’s transformation from human form to werewolf began with a two-stage prosthetic makeup, then progressed through animatronics and CG. Dudman’s team affixed contact lenses, teeth and facial prosthetics at the corners of Thewlis’ mouth to suggest Lupin’s mouth splitting back to his skull. A prosthetic back harness deformed Thewlis’ spine as his character’s jacket split apart, revealing canine back and shoulder blades beneath. Closeups of Lupin’s hands, with black nails exploding through the fingertips, and a shot of his legs elongating from his shoes were photographed later as animatronic inserts.

Digital effects take over as Lupin’s face erupts into a canine maw. The MPC shot began with a cyberscan of Thewlis that was tracked to a CG body, then selectively deformed. “Alfonso was keen to have a second of David Thewlis before he changed,” remarked Clutterbuck. “We slowed the shot to half speed, tracked in our CG puppet and match-animated it to David Thewlis in the shot.” MPC digitally replaced the performer’s hair with a Delilah simulation, animating the hair to spread and grow as the beast took shape, and also animated shaders to change his skin from pink to blue.

The werewolf in its final form begins to strike at Harry. When Sirius Black intercedes, transformed into the Grim, the two canines fight ferociously, ripping up the turf and crashing through the undergrowth. Roger Guyett photographed the fight as a series of tiled, locked-off plates that MPC later reconstructed and enhanced with postproduction camera moves. Artists animated the creatures with muscle animation, fur dynamics and flying clods of CG earth and drool, then applied 2D camera moves with appropriate motion blur. Delilah was used to generate interactive grass simulation beneath the creatures’ feet, with grass color and textures derived from vegetation in the plate.

As Harry and Hermione retreat from the battle, the camera rising, MPC keyed Radcliffe and Watson from the set and regenerated the environment digitally. “They couldn’t get the camera high enough



Seeking refuge near a lake in the forest, Harry and Sirius Black (Gary Oldman) are discovered and set upon by a swarm of dementors, who freeze the lake and attack them, until a mysterious energy erupts from the trees. Cuarón shot the sequence on a stage at Shepperton Studios. The physical effects team froze the lake by refrigerating layers of water over several days. ILM then animated both the freeze and the swarm of dementors, handcrafting keyframe characters and cloth simulations. The energy from the forest – a powerful wizard spell known as a ‘Patronus light’ – featured a 3D simulation with depth passes and mattes manipulated in 2D.

on set,” explained Peter Muyzers. “We were already generating a lot of grass, ferns and pine trees, so we took the move higher with a digital camera and extended the set.” MPC used Bionatics, a procedural 3D tree-growing software, to grow specific types of trees. “We bought ‘seeds’ for a library of trees, grew static models and applied Cantilever dynamics. We plugged those into Maya and used those forces to drive motion in the branches.”

In the final act, Harry and Hermione revisit their confrontation with Lupin and Black using a ‘Time Turner’ device that enables them to travel back and forth in time. Tim Burke supervised photography of the Time Turner journey — a long, fluid camera move that appears to transcend space and time. “Alfonso wanted to track around our two heroes as time went backward,” stated Burke. “The lighting changed from noon through to sunset; then, as they ran out, we followed, drifting through a clock tower and meeting them again outside. The only way to shoot the first part of the sequence was with a Steadicam; but we then had to isolate the children from the background for the time-lapse effect, controlling lighting on them and the background and getting them to marry up.”

After previsualizing the scene, Burke shot a Steadicam rehearsal of the actors running from the infirmary, using stand-ins to establish timings. Cinesite tracked camera motion, and The Visual Effects Company replicated the move using a Milo motion control rig on set with principal performers. The scene was shot in three sections. The first circled Harry and Hermione to a static position, revealing a bluescreen that separated them from the background as the time-slip took place. During the take, a technician carried a handheld light source up a ramp to the right of set, simulating the passage of the moon across the sky; to the left of frame, another technician walked up a ramp, casting light on the children that simulated the rising sun. The second portion of the shot picked up with the static time-lapse background, filmed at 12 frames per second, as nurses and other students zipped through the room. To simulate shifting sunlight outside the window, John Richardson constructed a motorized cable rig that towed a 20K light, controlled by motion control. The third part of the move trucked with Harry and Hermione out into the hallway, which was backed by greenscreen.

Cinesite assembled the elements. The compositors blended 4,000 frames of time-lapse characters inside the infirmary, compressing action into 200 frames, using motion analysis to create motion blur trails and Inferno effects to animate ghostly characters passing through Harry and Hermione. The Time Turner device — a spinning pendant held by Hermione — was shot separately using a physical effects rig in the performer’s hand. Cinesite step-printed the disk inside its ring to enhance the spinning motion. The camera then pulled back and glided out the door, revealing a CG set extension and CG clock mechanism at the end of the hall, built from orthographic designs.

The camera slips through the clock face — simulated by mapping ‘noise pattern’ displacement onto the plate to create the look of glass rippling the background, then dissolving from the distorted background to a clear background in 12 frames, effecting the illusion of passing through the glass. Harry and Hermione then run back into view below, entering a courtyard. The children were shot as a lock-off from a Strada crane, running through a bluescreen set at Leavesden. José Granell’s team constructed the surrounding courtyard as a 1/10-scale miniature. Cinesite combined the miniature and live-action and created a 2D camera move emerging from the clock tower. Animation

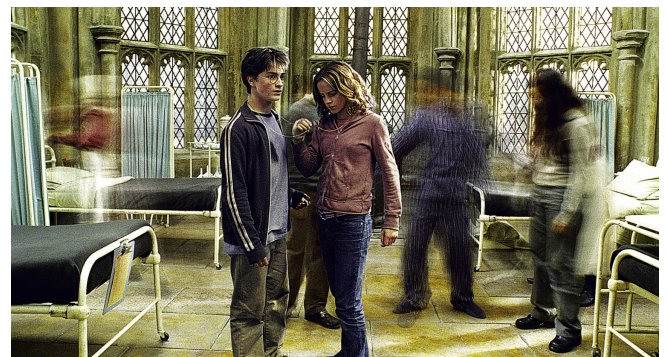
subcontractor *Baseblack* supplied a flock of crows that rose from the courtyard. Cinesite mapped in the birds and surrounding landscape, creating a 3D digital matte painting from Scottish scenic plates with additional painted vegetation, animated waterfalls and Hogwarts' miniature bridge. At more than 3,000 frames, the shot was equaled only by an epic reverse angle that retraced Harry's and Hermione's steps back into the infirmary later in the film.

The journey through time culminates on a frozen lakeshore, where Harry and Sirius Black — whom Harry now knows to be innocent of the crimes for which he was imprisoned — are overwhelmed by a swarm of dementors. Shot on a stage at Shepperton, the scene featured a practical frozen lake, which John Richardson created by laying down a bed of polystyrene, rigged with rubber pipes, then pumping refrigerant through those pipes to a cooling station outside the stage. Richardson's team built up a six-inch thickness of ice by spraying and freezing layers of water over a period of four days. ILM then digitally animated the freeze using a matte painting based on frames of the lake in its frozen and unfrozen states, matchmoved to animated CG fractals, with layers moving at different speeds to break up the leading edge.

To accommodate a dramatic view through the vortex of swirling dementors, each of them animated using dynamic cloth simulation and path animation, ILM shrank a down-angle of the Shepperton set by 1,000 percent, and expanded its perimeters with a digital matte painting. "We flew the skeletons around to work out timings in the funnel," said David Andrews. "Once the composition looked decent, we sent the animation over to cloth simulation and they built up layers. Alfonso directed the dementors like a force of nature, concentrating on the graphic composition of the shot. Nothing was procedural."

To dispel the swarm, Harry conjures a powerful spell, summoning a 'Patronus' light that dissipates the dementors' life-sucking energy. At the nexus of the Patronus, an animagus spirit appears in the form of a majestic stag. Gary Gero supplied a live animal performer for the main-unit shoot. Later, the ILM team, led by CG supervisor Michael DiComo, generated a digital double of the creature as a safety precaution and ended up integrating only the CG stag into the shots. "Sequence supervisor Anthony Shafer employed a Maya simulation that moved along the Patronus shape to create a watery effect," said Bill George. "Alfonso described it as 'liquid light.' We generated different depth passes and mattes made from that simulation, and then compositors created color and transparency."

Alfonso Cuarón's take on J.K. Rowling's text was based on the realization that as the characters and the readers of the *Harry Potter* novels were maturing, so must the films. The grittier, more realistic style



Back at Hogwarts, Harry and Hermione use a 'Time Turner' device to unravel the seemingly tragic events of their confrontation with Sirius Black. The scene was depicted in a single fluid shot that travels back in time as the camera exits the school infirmary, passes through castle corridors and a clock tower, then floats down into a courtyard. Live-action included multiple layers of motion control camera moves, choreographed with bluescreen separations, interactive lighting effects and time-lapse photography. Cinesite assembled elements with 2D effects then took the camera on the journey through a 3D clock tower mechanism to rejoin the live performers running through a miniature courtyard surrounded by a digital matte painting.

placed a new onus on visual effects and their integration into the fabric of the film. “The effects were much more organic to Harry’s world,” said Roger Guyett. “The creatures should appear as part of that world. Alfonso wanted to underplay them in a natural way, without making a big spectacle of every effects shot. I’ve worked on movies where we’ve been asked to always see the creature as big as possible, and always in focus. But when we talked about adding more detail to the dementors, for example, Alfonso insisted: ‘No, let’s just make it dark and shadowy. We don’t have to see every detail all the time.’ There’s a lot to be said for not having the effects jump out at you.”

“I think that may be why people are rating this as the best of the three films,” concluded Tim Burke. “Alfonso was very persuasive in his beliefs, and I think he made it a more interesting film — conceptually more interesting, and visually stunning.”

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Armed and Dangerous

image

ARTICLE BY JOE FORDHAM

Five days after Columbia Pictures' *Spider-Man* opened in May 2002, the studio, Marvel Enterprises and Laura Ziskin Productions announced that their arachnid-infected comic book crusader would be back on theater screens for a sequel in summer 2004. All principal players would return, including director Sam Raimi, whose passion for the source material energized the superhero tale beyond all expectations.

Whereas other comic book adaptations had met with mixed success — either departing from comic origins, adhering too slavishly to the comic text, or simply suffering from a surfeit of discotheque lighting — Raimi and team had succeeded in spinning 40 years of comic lore into a film that was part action-packed adventure, part human saga of everyday folk thrust into the Marvel Comics universe of mutant foes and heroes.

“One of the things that always attracted me to Stan Lee’s great comic books,” observed Raimi, “was the character of Peter Parker. The fact that Peter was one of us, grounded in the real world, all worked with the reader — and, in our case, the viewer.” Determined to maintain focus on the story and characters in his sequel, Raimi strove to answer questions set up in the earlier film. “I wanted to know what would happen between Peter and Mary Jane. Would they still love each other two years later? Would Peter’s friend Harry Osborn ever learn that Peter was really *Spider-Man* and had killed his father? There were a lot of pending issues. We tried to work every story element so that it reverberated with the story’s theme.”

While exploring Parker’s personal growth as a superhero in the sequel screenplay, Raimi returned to past collaborators at Sony Pictures Imageworks to develop visual effects strategies. “The trick was to figure out whether a particular event was worth the resources we would need to apply,” stated visual effects designer John Dykstra. “During scripting, the tendency is to come up with the wildest, craziest stuff you can. Then there is a winnowing down of those ideas, using a limiting factor of the resources that you are willing to expend. There may be a fantastic concept for a set piece in the first act, but if it consumes 80 percent of the resources, it leaves you lacking as you get toward the end of the film. From a technical point of view and from the storytelling point of view, that influenced where we took the characters — whether it was outside or inside, whether they built a complete set or shot on location.”

Filmmakers perused a catalogue of Marvel villains for the sequel, including The Lizard, Black Cat, and Doctor Otto Gunther Octavius, aka Doctor Octopus. In the end, Raimi chose to pit *Spider-Man* against ‘Doc Ock’ alone. “When I began to focus on what I thought the audience really wanted to see,” said Raimi, “which was a much more detailed portrait of Peter Parker’s relationships and problems, I didn’t think additional villains would further that end. We’d have to spend so much time getting to know these other characters, it would leave us with less time with the characters already established in the first film. I felt the audience wanted a much deeper experience with Peter Parker and the villain. Multiple villains ran counter to that idea and really were distracting.”

Doc Ock was a clear contender for the role of Spidey's nemesis, having made a lasting impact on comic book fans when he first appeared in *Amazing Spider-Man* #3, in July 1963, and going on to become one of Marvel's enduring super-foes. Originally conceived as an atomic scientist, Ock wore a harness that sprouted four telescoping titanium steel tentacles, with a tripod claw at the end of each. The apparatus was designed to handle radioactive objects until, in true Marvel style, a laboratory accident fused the scientist to his creation and left him criminally insane.

As depicted in the *Spider-Man 2* screenplay — written by Alvin Sargent, from a story by Alfred Gough, Miles Millar and Michael Chabon — Octavius (Alfred Molina) is a scientific genius on the brink of harnessing a potentially revolutionary energy source. Before his accident, he forms a friendship with young student reporter Peter Parker (Tobey Maguire). Parker's own story intertwines his continuing romance with Mary Jane Watson (Kirsten Dunst) and his inner turmoil in maintaining a double life as a clandestine crime-fighter. Parker's wrenching ambivalence yields to his higher calling when, after Octavius' transformation, *Spider-Man* rallies to save the metropolis from the doctor's goneawry energy experiments.

Methods for realizing Peter Parker's new adversary required a long gestation. Ock's evolution began with costume designer James Acheson, who brainstormed concepts with production designer Neil Spisak, Raimi and Dykstra, using comic book reference as a springboard for discussion. "The comic book frames were very evocative of emotional content, based on body language," John Dykstra observed. "The problem was, they were still frames. One of the toughest things we had to do was make this 'octopedal' character move in a way that was a cross between organic and mechanical, to make him believable and formidable."

Imageworks CG character animation supervisor Anthony La Molinara and his team generated animation tests to explore literal interpretations of Doctor Octopus' name. "An octopus underwater is virtually gravity-free," related Dykstra, "but if you translate that style of movement to dry land, it looks balletic and too graceful. We wanted to create organic movement, a sense of Ock controlling his tentacles on a neural basis, as opposed to controlling them with a knob or button interface. He controls them cerebrally, so they anticipate his moves and adjust their position to compensate for his center of balance. They had to be jointed, but not like limbs. They had to be completely flexible, almost in a snake-like fashion, but they had to have a hierarchy of movement that made mechanical sense. Tentacle motion had to propagate from the mass of Ock's body — so if one tentacle extended, another went out the other way to compensate and balance."

Tentacle behavior was also tied to a narrative arc, the appendages nothing more than harmonious extensions of Ock's limbs early in the story, then later gaining a will of their own. "This was derived from an idea called 'distributed processing,'" said Dykstra, "which we discussed extensively with the scientific consultants on the film. In distributed processing, local hypothalamic processes enable an octopus' tentacle to pursue an assigned task even after it is severed. We included that concept in our



Two years after *Spider-Man* swung into theaters, the Marvel Comics superhero returned, again under the directorial aegis of self-confessed comic book fan Sam Raimi. Rejoined by visual effects designer John Dykstra, physical effects supervisor John Frazier and digital effects

thinking about Ock; so, as the story progresses, the tentacles go counter to him, compelled by an overriding desire to create this fusion reaction — and they take their parasitic host with them. They affect Ock’s decisionmaking, and it becomes a battle of the wills between the tentacles and Ock.”

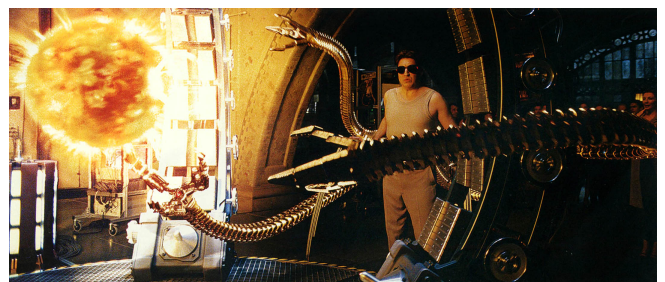
artists at Sony Pictures Imageworks, Raimi picked up the narrative where he left off, expanding on themes explored in the first film. Spider-Man 2 filled a broader widescreen canvas with spectacular action, but remained a character-driven tale in which beleaguered webslinger Peter Parker (Tobey Maguire) struggles to defend his loved ones against a formidable new villain.

The first tentacle mockup took shape in Acheson’s costume department, where plastic tubing was strung around a stand-in dressed in Ock’s trademark full-length duster coat. Acheson then recruited a team of artists to develop artwork and computer generated designs, and investigated the practicalities of constructing mechanical tentacles with Edge FX animatronic designer Steve Johnson. “I wanted the tentacles to be real puppets whenever possible,” observed Sam Raimi. “Consciously or unconsciously, an audience knows when something is really there in shot. I felt practical puppets would bring subtleties to the performances by interacting with the actor when the camera was rolling. A lot of the life of the tentacles came through Alfred Molina’s performance. He imbued them with that life through his reactions, through his eye contact with them.”

Edge FX built foamcore mockups of tentacles for motion tests early in preproduction. “We worked without a script for the first six months,” stated Steve Johnson, “imagining what components we would need and figuring out how to manipulate them.” Johnson took advantage of the creative range of possibilities by recruiting a team of Screen Actors Guild puppeteers to work Edge at FX with his studio engineers. “By working with us through production, the puppeteers became intimately connected with the puppets, and Sam could direct them as if he was directing a performer.”

As Edge FX finalized designs, the team created Fastcast resin castings of tentacle segments that resembled heavy metal vertebrae. “Weight was always a key issue,” said puppet master Eric Hayden. “We tried producing pieces using vacuform, but ended up using self-skinning expandable urethane foam to keep everything lightweight.” Hayden and model shop supervisor David Merritt oversaw production of several thousand components used in more than 200 animatronic puppets. Vertebrae were molded, cast and sealed, then nickel-plated and fitted over flexible polypropylene tubing, interspersed with rubber grommets. Artists detailed tentacles with dark, mechanical interiors, using an industrial yellow patina along the backbone to produce a weathered metallic look.

Rather than pursue extensive mechanized articulation, Edge FX relied on marionette and rod control, augmented by radio control. “We constructed animatronic tentacles,” stated Johnson, “but we used them as little as possible. Our directive was to make the tentacles work as directly and as simply as possible. The tentacle puppets were fairly flexible, and we controlled the movement either by wires on an overhead gantry or custom-built booms. Each tentacle had a fully animatronic claw. We attached a boom to the claw, where the heaviest



Doctor Otto Gunther Octavius (Alfred Molina) is a charming, if eccentric genius until a laboratory accident fuses the scientist to a bizarre mechanical invention and leaves him criminally insane. Octavius was one of Marvel Comics’ enduring super foes, commonly known as ‘Doc Ock,’ characterized by four telescoping titanium steel

weight was, and used a wheeled fulcrum joint above so that we could move forward and back. The plan was to remove any rods, wires or puppeteers digitally.”

appendages that enable him to indulge his megalomaniacal tendencies. The filmmaking team transformed Molina into Spider-Man’s eight-limbed nemesis using combinations of physical effects, animatronic puppetry and digital effects. Wide shots in Ock’s lab featured digital prostheses in combination with the actor.

Each claw also contained remote controlled ‘digits’ and expressive lighting, operated via radio control.

“The tentacles had running lights and what we called the ‘heartlight,’” observed Hayden, “which was the eye of the claw. We rigged super-bright, color-shifting, light-emitting diodes that focused light into a lens. Using radio control, we could dial up the intensities of any color at Sam’s direction.”

To create the effect of tentacles unfurling to their full 25-foot span, Edge FX adopted a modular approach, building lengths of tentacle in three-foot sections that could be fastened and unfastened with metal air-hose connectors. “If we needed three feet of tentacle with a claw,” explained Johnson, “we could take a three-foot section and snap the claw right on. If we wanted six feet, we’d add a second three-foot length — and so on. We also had variations of vertebrae spacing, expanded and contracted so that if the tentacles got longer, the vertebrae would be spaced further apart.”

Crews affixed the tentacles to a girdle that wrapped around Molina’s waist and back. Costume department sculptor Kent Jones crafted a full-scale clay sculpture of the girdle. Edge FX then molded the form and generated nickel-plated resin pieces as a rigid cowling that the tentacles clipped into via quick-release connectors. In addition, Edge FX constructed a separate metallic self-latching mechanism, for closeups of the girdle snapping closed, and soft rubber versions of the girdle for extended wear.

When a shot required all four puppet tentacles, Edge FX erected a 25-square-foot steel frame that stood 12 feet above the set and supported a system of tracks and pulleys over which puppeteers could string 1/8-inch steel cables attached to the tentacles. Operators manipulated the cables using retractable dog-leash mechanisms, which enabled puppeteers to retreat, keeping cables taut, to a distance of up to 25 feet. To create additional spring and snap, Edge FX affixed bungee cords to the undersides of the tentacles, rigged to pulleys on the apparatus below.

As many as 16 operators wrangled the tentacles using the full puppet rig, interacting with Alfred Molina at its center. Despite the discomforts of the 75-pound apparatus, Molina developed a lively rapport with Edge FX puppeteers through rehearsals and the shoot. “It wasn’t easy for Alfred,” stated Steve Johnson. “Essentially, he was strapped into a giant torture device on a daily basis. What made it work was that Alfred and Sam wanted it to work. If we needed a specific action with the tentacles and it wasn’t working in a certain configuration, Sam would rethink his shots and break the action into pieces — as opposed to saying, ‘Screw this, we’ll do it digitally.’”

With much of the movie’s action dependent on the success of the tentacles’ performance, the production scheduled a proof-of-concept test to examine animatronic viability one month before principal photography. “The producers and Sam wanted to see how much the puppets would be able to perform,” remarked Johnson. “They decided to test that by shooting a sequence in which the tentacles would perform a lot of action. After Octavius’ accident and the tentacles are fused to him, he wakes up in a hospital, goes berserk, tears apart an operating room and kills the medical staff.

We planned 90 percent of the shots in that sequence as practical effects — and if we got through the scene, we'd know the puppets were going to work. If they didn't work, the production would have to come up with a different approach. There was a lot of pressure on us to perform, but it worked really well because we were able to rehearse and test all our shots in advance. By focusing on that first sequence — testing every shot a variety of ways and getting them approved by Sam — when it came to shooting, it went like clockwork.”

Shot at Sony Pictures Studios, the scene required ten puppeteers for wide shots of tentacles writhing behind Ock. Edge FX used rubber claws tied to stunt performers and wire harnesses furnished by stunt coordinator Dan Bradley and physical effects supervisor John Frazier for shots of victims in tentacle death-grips. For closeup actor/tentacle interaction — as in a shot of one probing appendage removing bandages from Doc Ock's eyes — a hollow tentacle puppet fit over an Edge FX puppeteer's arm. “We called our closeup arm the ‘sock puppet’ tentacle,” observed Eric Hayden. “Two puppeteers, Donna Kimball and Patrick Gerrety, had thin enough arms that they were able to fit inside. Then we radio-controlled the pincers that came out the end.”

Less mechanically feasible scenes were achieved using digital animation. Decisions as to when to use which technique were determined by the rigors of the shoot. “It might have been possible to shoot the whole film with puppets,” observed John Dykstra, “but it would have been impractical. A 12-foot-long tentacle took four puppeteers to manipulate. Four tentacles would have required four times the number of puppeteers. If we had Doc Ock walking down a hallway with all four puppet tentacles, a very large crowd of puppeteers would have to be there, either with him in the hallway or off-screen operating cables. And it was tough to get a performance with everyone moving synchronously. A motion picture set is a place for innovation, not a place to execute highly rehearsed events. Consequently, we used the practical puppets for closeups, mostly, where they came in from off-screen; beyond that, we used CGI.”

To assist the integration of digital effects, Raimi and Imageworks shot clean plates without practical tentacles, Molina reacting to imaginary tentacles. “The safety plates helped with digital paintwork to remove the puppeteers,” related Imageworks visual effects supervisor Scott Stokdyk. “They also gave us the option to go all-CG if we wanted. The puppeteers wore blue suits if we were shooting against bluescreen and, overall, they were very good at keeping out of the way whenever possible. But for medium or wider shots, where they had all four arms going, they sometimes had 16 people working tons of wires, which required a lot of digital paintwork to remove. So, in general, when we shot with the puppets, we almost always shot a clean version of the shot. We used those plates a lot as Sam shaped the story in postproduction.



Animatronic designer Steve Johnson and production designer Neil Spisak observe as costume designer James Acheson and John Dykstra attend to a prototype of a Doc Ock tentacle claw during preliminary testing at Johnson's Edge FX. Acheson and Spisak led Ock's tentacle design, exploring various materials and concepts with art department, wardrobe, animatronic and digital designers. Tentacle puppets were built as lightweight as possible, designed to afford maximum expressive movement with minimal burden on the performer.

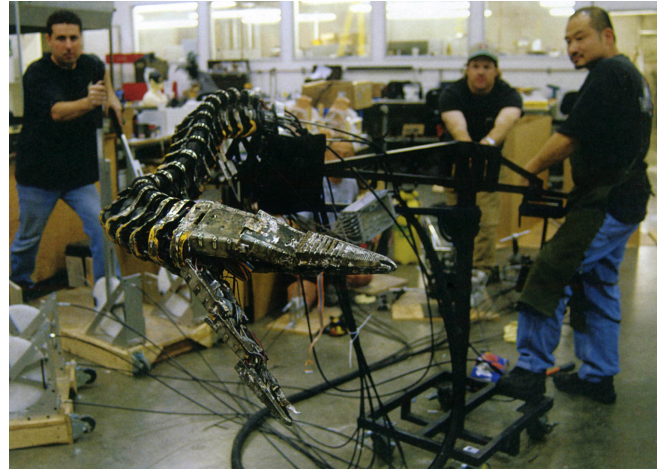
He sometimes had us create CG tentacles because he needed a certain action to bridge a cut; or, sometimes, he shuffled shots around to make a slightly different story point.”

Imageworks’ CG tentacles intercut practical tentacles and occasionally shared closeups with Molina. To match the rich detail of the Edge FX creations, Imageworks conducted 40 cyberscans of tentacle components at Gentle Giant Studios. Modelers then used the data to create a CG tentacle construction kit in a similar fashion to the practical puppets. “Our tentacles extended much further than the practical tentacles,” said CG supervisor Peter Nofz, “but animators could reconfigure how the tentacles were put together a lot like the Edge FX tentacles on set, assembling them in chunks. An animator could select three medium vertebrae here, five thin vertebrae there, build the tentacles on the fly, and then keep on animating.”

Ock character physiquing lead Aaron Campbell built animation controls that allowed tentacles to move independently or react with sinuous follow-through to the motion of Molina’s body. Animators could change the spacing between vertebrae, like a Slinky toy, as tentacles expanded and contracted. Tentacles could also be animated to resonate with shock waves that rippled down their length on impact with objects.

Unlike the Green Goblin of the first film, Doc Ock would remain unmasked throughout the sequel, posing an added challenge to Imageworks when creating an Ock digital double. “I definitely wanted an unmasked villain this time,” Raimi remarked. “I loved what Willem Dafoe did in the last film as Green Goblin; but as soon as I had a masked Green Goblin interacting with a masked *Spider-Man*, I lost all the humanity.”

Ock’s exposed skin, flowing coat and hair — seen in broad daylight, scaling buildings and grappling with *Spider-Man* in perilous environments — required extensive research to determine a technically appropriate digital modeling solution. “We knew that Ock’s CG face would be critical to our character,” noted Scott Stokdyk, “but there were two camps as to the best approach. Some of our crew had worked on *Final Fantasy* and wanted to take that technology to the next step, building the best texture maps and shaders in the world, with built-in subsurface scattering — the latest craze in shader writing — and spending a lot of time dialing in materials. Other people, myself included, felt there were artistic limits in how far we could take that. When you build a CG face using texture maps and shaders, the process can break down. A texture painter has to decide on saturation, sharpness, exposure and correcting projection problems when they project textures onto the model. Shader writers also have to make approximations of values, mimicking the real world. The



Edge FX constructed more than 200 animatronic puppets for the film, including fully mechanized articulated tentacles, actuated by cable control with radio controlled claws, prehensile ‘digits’ within the claws and interactive lighting. Vertebrae were molded, cast and sealed, then nickel-plated and detailed with dark, mechanical interiors, creating a weathered, metallic look that belied the puppet’s lightweight construction. To reduce the technical complexity of puppetry on set, however, the majority of practical tentacle shots did not feature fully mechanized puppets, but instead used flexible puppets marionetted via rods or an overhead wire rig, with radio-control claw detail.

alternative was to acquire textures of the performer's real skin and place the artistic choices in the lighter's hands. We could then decide on light position, intensity and color, as opposed to trying to re-create reality and then figure out why it didn't look real."

The image-based rendering approach began by cyberscanning Molina in full Ock regalia, then photographing the actor in a lighting rig at the University of Southern California's Institute for Creative Technologies Light Stage 2. The Light Stage setup required Molina to sit before a vertically mounted crescent of strobe lights, with four equidistant 35mm motion picture cameras aimed around his face. As Molina emoted, lights swung in an arc around him, synchronized to flash with each film frame as cameras ran at 60 frames per second. Imageworks recorded 480 images of Ock expressions per pass, scanned film frames at high resolution, and then projected images onto cyberscan geometry of Molina's face, modified to line up exactly.

Imageworks sampled progressive images of Molina's face and extracted variations in light levels and specularity on the actor's skin. When placed into virtual environments — derived from high dynamic range digital photography — the CG model was lit with real-world lighting values. "The CG skin was not a shader function," Peter Nofz commented. "It was really Alfred's skin. We could sample hundreds of textures to see how the skin responded to the light at certain angles, so it was more a 'lookup' approach than a calculation. It took a team of six people six months to develop that idea from research to production. It was a pretty simple — but brilliant — idea."

To bring the CG face to life, Imageworks extended its existing facial system setup, introducing facial motion capture into the animation pipeline. John Dykstra and Anthony La Molinara directed motion capture sessions with Tobey Maguire and Alfred Molina at The House of Moves. The performers, in black caps and T-shirts, and with some 100 tracking marker dots on their faces, enacted facial expressions, providing animators with a palette of emotions. "We could have modeled Alfred's face and tried to duplicate his expressions," remarked La Molinara, "but we were trying to duplicate a real person, with all of his idiosyncratic movement — so why not motion capture the real thing and use that facial movement? It was similar, in theory, to a Claymation technique I had used at Will Vinton Studios on the 'California Raisins' television commercials. We literally shot live actors on 35mm film and then, frame-by-frame, sculpted caricatures of their expressions. We created a huge bank of expressions to use anywhere we needed in the show."

While Ock was in development, digital and physical manifestations of *Spider-Man* were also given a shakedown. Amalgamated Dynamics Incorporated, which had worked with James Acheson to create the form-fitting *Spider-Man* suit on the first film, produced 35 new Spidey suits, streamlining the design and the manufacturing process. "The first version was basically a prototype," noted A.I co-founder Alec Gillis. "Jim went through areas he wanted to improve, and we redid all the work with the exception of the muscle suit underneath the spandex. We refined the raised webbing on *Spider-Man*'s face and the logo on his chest and back, and devised new lenses, which were less translucent with better magnetic attachment."

Improvements to the costume, though subtle, were sufficient to warrant an overhaul of the computer generated double. Imageworks re-scanned the costume, modified *Spider-Man*'s jawline to provide slightly more expressive facial movement, and generated new web lines using a procedural RenderMan technique. Physiquing and musculature remained otherwise intact. "Koji Morihiko did such a great job setting up the *Spider-Man* puppet," said Anthony La Molinara, "we used the same rig as last time."

Spider-Man's CG city also received attention, catering to more ambitious shots devised by Raimi for the sequel. Despite the extensive modeling previously invested in creating digital sections of



For closeup scenes requiring prehensile action, Edge FX used a 'sock puppet' tentacle — often in collaboration with physical effects rigs that towed selected objects into the tentacle's grip — allowing puppeteers to seize items that included sacks of cash, hats, cigars and Tobey Maguire's neck. During a tense exchange with Peter Parker, Doc Ock

downtown Manhattan — two years of texture painting and constructing 50 structures from photographic reference — Imageworks returned for more. “Last time, we found that our fly-throughs were limited because of the limited number of buildings we modeled,” noted Stokdyk. “If we were flying through a street, we would see a Flintstones effect with the same building going by a couple of times; so we needed more buildings for longer swings.” Imageworks returned to New York and acquired data to construct 19 new buildings, using a slightly modified approach. “We went a little heavier on modeling than texturing this time. 3D gave us more effective textural displacements, relying more heavily on ambient occlusion to create lighting effects. It gave us a little better realism and higher-quality details.”

While added detail allowed *Spider-Man* greater interaction with the building exteriors, high dynamic range image maps of offices allowed increased interactive lighting detail in interiors. “Having HDR source material meant interiors could work equally well for day and night,” said Stokdyk. “Exterior light sources influenced the interior; so if we had a red light glow from building signage, it could illuminate interior colors. If we had a corner office, we could have light shining through one set of windows and then going out another. We also added indirect lighting effects, where the sun bounced off one window onto another and made dappled patterns on the ground or another building.”

The density and detail in the new CG buildings freed up their placement into scenes. “On the first film,” said 3D environment lead Dan Abrams, “we only dressed certain parts of certain buildings — but we ended up having to see all of them because we needed so many buildings. This time, every building could withstand scrutiny from every conceivable angle. This meant our texture painters had to cover huge amounts of ground. Each building had, on average, 14 texture maps at 4K each. In real-world space, each map covered approximately 150 square feet, so it felt like physically painting a real building. It took over a year to construct 19 buildings to that level of detail.”

Practical and virtual locations are featured in the opening of the film, as Peter Parker adopts his *Spider-Man* persona to assist his real-world job of pizza delivery, swooping and swinging through skyscraper canyons. The sequence is followed by a spectacular nighttime car chase — shot on location in New York and on the backlot at Universal Studios — in which Parker runs afoul of criminals in a high-speed getaway. The sequence included a Spidey swing, down the length of a city street, which passes between the cab and trailer of an 18-wheeler truck. “That was a CG character

adjusts his sunglasses, enacted by puppeteer Donna Kimball, while an off-camera operator choreographed radio-controlled digits. Edge FX achieved the close interplay of performers and tentacle puppets by rehearsing puppeteers for six months concurrent with the design and construction of the animatronic pieces.



For some shots, blue-spandexed puppeteers manipulated Ock tentacles via rods against bluescreen, avoiding obstruction of the actor's face and wardrobe as much as possible. Sony Pictures Imageworks keyed Molina and the puppet tentacles from the bluescreen footage, then digitally reconstructed areas where rods crossed the actor, and composited the Ock character against clean background plates. Clean plates also allowed Raimi to restructure scenes during postproduction, tightening story points using CG tentacles. Imageworks built CG versions of the tentacles, based on cyberscans of practical tentacle components, and then textured, lit and rendered digital facsimiles to intercut and share closeups with Edge FX creations.

and a CG truck,” said John Dykstra. “We shot a plate in downtown Los Angeles using Earl Wiggins’ wire-flown ‘Spydercam’ rig, and then we added the truck. We also shot a swing in Wall Street that started 22 stories above the street, dropped down to about three feet from the ground and then went back up again, extending 4,000 feet from one end to the other. On this movie, Sam wanted more vertigo and more extensive camera moves.” Physical effects and stunts combined to pummel cars and send a police vehicle careening through the air. Digital animation of *Spider-Man*, flying automobiles and animated webs augmented the live effects.

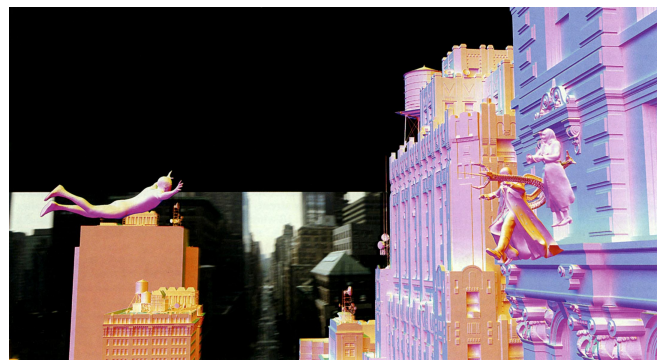
After establishing Peter Parker’s struggle with a dual identity as superhero and beleaguered science student the story introduces Doctor Octavius as the subject of a college paper Parker is writing about Octavius’ cold fusion energy research. A demonstration goes haywire as the fusion reaction sucks all metallic objects into its vortex and, despite *Spider-Man*’s intervention, destroys the room and leaves Octavius forever changed.

The fusion event itself was depicted as a glowing orb, suspended in midair, designed to resemble spectral photography of solar flares. Dykstra commissioned New Deal Studios to produce a custom rig to simulate lighting effects of the fusion event on set. New Deal modelmaker Brian Kelly Hahn constructed an armature for supporting 11 par lamps, arranged in a bouquet around an L-shaped metal bracket. With the horizontal arm of the bracket oriented away from camera, the device provided a 360-degree ball of light that illuminated the environment from the center of the fusion machine. Imageworks animator Theo Vandernoot then created a digital effect to replace the ball, generating 3D spheres, nested inside one another, covered by particle effects and hair-like ribbon primitives that wafted menacingly from the surface like tongues of flame.

Imageworks adjusted contrast to emphasize a blinding plasma effect as the event takes hold. “The conceit we came up with was that the event should be like looking at an arc through welder’s goggles,” related Dykstra. “The arc at first appears so bright the flare is devoid of detail. Through welder’s goggles, the surrounding image becomes dark, but the arc is visible with the envelope of gas around it



During a bank robbery to fund his experiments, Ock takes Peter’s Aunt May (Rosemary Harris) hostage, and, walking on his tentacles, carries the woman up the side of the bank building while fending off Spider-Man’s attacks. The physical effects team devised an Ock walk rig to hoist Alfred Molina above the set to simulate the motion of Ock’s body being displaced by the lumbering tentacles. The rig was sometimes used against bluescreen, but more often in live-action environments, with CG tentacles added in post. The majority of Ock’s ambulatory scenes featured digital doubles of Molina, Tobey Maguire and, occasionally, Rosemary Harris as Ock hauls her character up the bank exterior, where the fight with Spider-Man continues.



Imageworks generated an array of buildings to increase its existing library of digital structures. Artists returned to New York to acquire architectural data and then modeled structures, relying on 3D textural displacements and ambient occlusion to create lighting effects. The higher-quality details allowed 3D cameras and characters greater interaction with the building exteriors, while high dynamic range image maps of offices allowed for increased interactive lighting detail inside. For wide shots in the

and the molten metal. That was what we did with the fusion ball — we dampened the exposure on the environment to create the effect of seeing the event through welder’s goggles.”

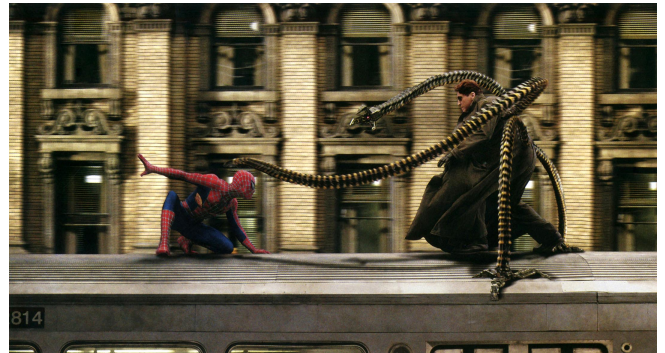
After the catastrophic failure of the demonstration, a hospital medical team attempts to sever Ock’s mechanical appendages, to disastrous effect. The scene employed the full gamut of practical Edge FX creations, combined with camera speed effects that gave practical tentacles savage whip and thrust. “We played with a lot of different camera speeds,” said Raimi. “My great stunt coordinator, Dan Bradley, recommended particular speeds; then, in postproduction, if ever we had guessed wrong, my editor Bob Murawski manipulated speeds in the Avid.” Imageworks furnished coup-de-grâce digital effects for wide shots of tentacles writhing operatically, light streaming behind Ock as he wakes to the sight of the horror he has wrought.

For a shot of Ock, supported by his tentacles, staggering from the hospital into the street, Raimi shot Molina on the New York street backlot at Universal Studios wearing only hospital bedclothes and the tentacle girdle. Imageworks then animated tentacles to walk with the performer in the wide shot. “We played with many different ideas for Ock’s tentacle walk,” recalled Anthony La Molinara. “Early storyboards had him using one tentacle to walk and the others to fight; but only certain sculptural forms looked attractive, and it seemed to work better with him walking on four.”

The scene continues with closeups of Molina in the Edge FX full puppet rig and wide shots of Ock batting away a taxicab with CG tentacles, animated with close attention to physics. “We had to consider how much weight Ock could support,” stated La Molinara. “If Ock did not have any particular superhuman strength, how could he hold up all these tentacles that looked as if they weighed 500 pounds apiece? And if he was standing on his own two feet, how could he throw a car? The solution was to consider the logic of those shots and then see what we could get away with. It was all about trying to bring the audience into this fantasy, and making them believe it.”

Tentacle locomotion is seen in all its glory during a bank robbery precipitated by Ock, in search of funding to continue his fusion experiments. Coinciding with a bank visit by Peter Parker and Aunt May (Rosemary Harris), the heist turns into a free-for-all between Ock and Spider-Man. Tentacles first

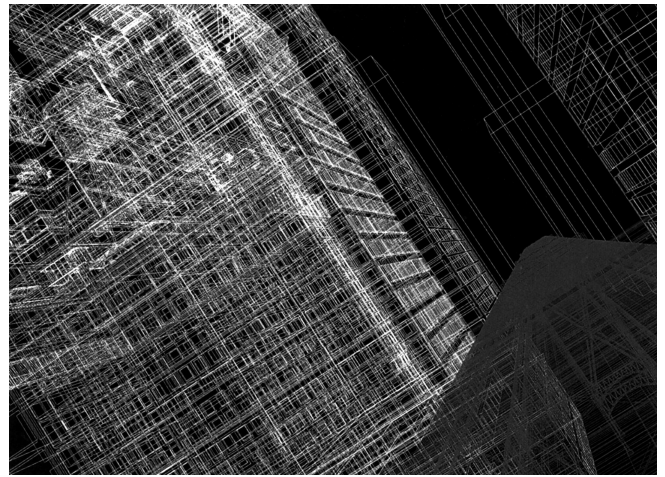
bank exterior battle, compositors layered CG environments and characters against a digital tile of live-action background plates shot on New York City locations. The digital Spider-Man required new modeling and paint to match the costume’s slightly modified appearance for the sequel. The CG Doc Ock — with his exposed skin, flowing hair and costume — required extensive research and development that resulted in an image-based rendering approach, where CG models were built and lit with real-world lighting values. Ock’s flapping trenchcoat was generated using an object-based modeling paradigm that sampled cyberscan textures of Alfred Molina in costume.



Ock later lures Spider-Man into a showdown on a runaway elevated train. The sequence involved footage shot on location in Chicago and New York, and on bluescreen stages in Los Angeles, coupled with digital environments generated by Imageworks. John Dykstra shot motion picture tiles from a moving Chicago rail car, using an array of synchronized cameras. Imageworks stitched the image tiles together, filled out backgrounds with digital New York structures, and created camera moves in postproduction. Chicago plates provided backgrounds for bluescreen photography of actors aboard physical effects gimbal rig reconstructions of the train.

deploy from Ock's lower back, appearing from underneath his coat in another instance of digitally animated sleight of hand. "We never let the audience see exactly how the tentacles unfurl," stated La Molinara. "In early designs, the tentacles went all the way into his back, and there were different theories to explain that. Eventually, we decided the tentacles should never retract shorter than six feet; and they could extend to 25, telescoping but not feeding right out of his back. We sometimes cheated the space between vertebrae so the extended tentacles did not look too flimsy and maintained an acceptable sculptural feel and strength."

Physical effects rigged windows to shatter, furniture to smash and a taxicab to implode — all in reaction to digitally animated props and Ock himself hurled about the scene. Amid the mayhem, Edge FX used sock-puppet tentacles for closeup inserts of Ock grabbing sacks of coins from the bank vault. "Physical effects rigged wires to the bags of money," Eric Hayden said. "The claws reached in and grabbed — they couldn't really lift the heavy sacks — physical effects pulled the wire and we pulled it out of frame. There was constant teamwork between Edge FX and John Frazier's crew."



Dynamic shots of Spider-Man and Doc Ock clinging to the sides of the speeding rail car, dodging overhead bridges and passing trains, featured entirely digital environments and characters. Imageworks fashioned a virtual set of the elevated train and skyscraper canyon that stretched, in one shot, for 30 city blocks. Digital artists generated low-resolution versions of buildings for far distance, more detailed CG structures for foreground, with 3D geometry of the train and rail supports. Sections of the track were repeated, with shapes and dimensions of the rails varied procedurally in the composite.

Ock's fight with *Spider-Man* decimates the bank and reveals Ock's ability to rise up on his tentacles. John Frazier devised an Ock walk rig to hoist Alfred Molina above the set using a system of cables and pulleys to simulate the motion of Ock's body being displaced. The rig was occasionally used against bluescreen, but mostly in live-action environments, with CG tentacles added in postproduction. The majority of Ock's ambulatory scenes featured digital doubles of Molina, *Spider-Man* and, occasionally, Rosemary Harris as Ock seizes the elderly woman, making his escape up the bank exterior, where the fight continues.

The bank exterior fight utilized horizontally mounted wall-walking sets and virtual environments, requiring extensive cloth and hair simulations in shots of the CG Ock, his coat flapping about his writhing tentacles. Imageworks took advantage of new CG cloth research underway at the studio and applied an object-based modeling paradigm to cloth creation, as opposed to panel-based cloth simulation used on previous shows. "Panel-based cloth gives great control over cloth behavior," said Scott Stokdyk. "We were very familiar with its strengths and weaknesses, but the theory is that object-based cloth creates more realistic wrinkles by sampling real material." Imageworks developed Ock's CG wardrobe from cyberscans of Alfred Molina in costume. "We used the cyberscan of the complete object with wrinkles baked in. Ock's costume ended up being very challenging because it was unlike anything we'd done before — long and flowing, rather than discreet pieces that fit parts of the body. And it was a two-layer costume of a trenchcoat on top of a leather undercoat; so the outer coat had to react to the inner coat as a simulation on a simulation. The overall dynamics-to-wrinkle ratio became more complicated the bigger it became; and Alfred was a big guy, so it was quite a setup problem."

The bank raid scene is followed by a sequence in which Peter Parker, in civilian guise, attempts to rescue a stranded child from a burning building. John Frazier's team executed a controlled pyrotechnic burn on backlot and soundstage sets. Radium Effects — one of several subcontractors assisting Imageworks — performed wire and rig removals and composited blue-screen footage of Tobey Maguire into conflagration shots, layering in fire and smoke elements and particle animation sparks.

Zoic Studios also assisted with a handful of shots in the fire rescue sequence and created composites for a later scene, set in a downtown diner, where a romantic interlude between Parker and Mary Jane is interrupted by a car, tossed by Ock, crashing through the window. John Frazier's team staged a practical effect on the Universal backlot, launching a Saturn Ion from an air cannon



Dynamic shots of Spider-Man and Doc Ock clinging to the sides of the speeding rail car, dodging overhead bridges and passing trains, featured entirely digital environments and characters. Imageworks fashioned a virtual set of the elevated train and skyscraper canyon that stretched, in one shot, for 30 city blocks. Digital artists generated low-resolution versions of buildings for far distance, more detailed CG structures for foreground, with 3D geometry of the train and rail supports. Sections of the track were repeated, with shapes and dimensions of the rails varied procedurally in the composite.

previously used for launching aircraft in *Pearl Harbor*. Effects technicians removed the Saturn's engine to reduce the vehicle's weight and added rigging to connect it to the launching device. Zoic Studios generated a 3D model of the underside of the vehicle to fill the cavity and replace the rigging. Dykstra shot clean plates of the background outside the window and plates of pedestrians and street traffic. Zoic tracked in the Saturn's underside, rotoscoped and assembled background action in 2D layers. Imageworks enhanced the scene with shattering glass and bluescreen elements of Maguire, Dunst and their stunt performers dodging the flying car. For a slow-motion closeup of the couple sailing through the air, Parker's cheek narrowly evading a Saturn wheel, Raimi shot Maguire and Dunst leaping onto an off-screen crash mat in the diner set; Imageworks then composited an element of a full-scale car shot on a bluescreen flying rig. The final crash was practical.

Ock enters the devastated diner — Molina in his walking rig, surrounded by animated tentacles — and confronts Parker and Mary Jane using Edge FX puppets literally in the actors' faces. "The diner scene was one of my favorite gags in the film," declared Eric Hayden. "We were still in the early part of shooting and hadn't necessarily earned the trust of everyone on set. Ock was supposed to grab Peter Parker and drag him to within inches of his face using this long tentacle. We offered to do the shot with a puppet. The other departments weren't so sure. Sam was not so sure. When we pointed out that we were going to have Tobey in the tentacle claw for the next setup, they let us have a go."

The Edge FX crew attached the claw to Maguire's neck, the performer and the tentacle supported from overhead, then puppeteered the action in three takes. The gag received a thumbs-up from Raimi. "We didn't even need to shoot a clean plate for CG coverage for that scene because it whipped by so fast," said Hayden. "Moments like that made us feel as if we were really part of the movie. Anytime we got a real claw around Tobey's neck, it felt good!"

Puppetry and digital effects were pushed to the limits for the film's centerpiece action sequence, in which Ock attempts to lure *Spider-Man* to his doom by kidnapping Mary Jane and arranging a rendezvous on a highrise clock tower. Powering through the city, the superhero swoops through four giant arcs to land on the clock tower cupola where Ock is waiting. The two clash in a flurry of limbs, tentacles and flapping fabric. "Ock and Spidey fall off the building and land on top of a speeding train," related La Molinara. "All the tentacles were flying, becoming mixed up with the cloth. We had to go over the animation again and again because the cloth intersected with the tentacles — and it was easier to fix the movement of the character or the tentacles than it was to deal with the cloth."

Spider-Man's fight with Ock on, in and around the elevated train was the first sequence to be filmed. After storyboarding and previsualizing the scene, the filmmakers traveled to Chicago in November 2002 — four months before principal photography — and began an eight-day shoot on a Chicago Transit Authority train redressed with New York subway decals to stand in for Manhattan's Third Avenue 'el,' which last ran in 1955. "Not to be stopped by the nonexistence of elevated trains in New York,"



remarked John Dykstra, “we shot plates in Chicago. We also built CG trains and added CG New York buildings to Chicago plates; but the purpose of the Chicago shoot was to capture as much as we could in plate form to avoid having to create CG buildings for every shot in the sequence.”

Dykstra staged the Chicago shoot using a train car that sprouted 16 cameras. “We shot locked-off motion picture tiles using arrays of three synchronized cameras,” Dykstra elaborated. “We stitched the tiles together to create moving background plates against which we could place our CG character or bluescreen characters, and then created camera moves in postproduction. We had monitors inside the train while the cameras shot out the side, out the roof, off the front, off the back, off the bottom and down by the rails. We had to take it all apart every evening, because the train worked in the mornings, and then put it all back together the next day. Plus, it was winter, so we had short days and it rained the whole time!”

The Chicago footage served as the basis for backgrounds viewed from camera positions low on the train roof and inside, looking out at passenger level. “We couldn’t get the camera too high on the roof,” observed Scott Stokdyk, “because we were traveling under low overpasses. After the Chicago shoot, we blocked out what shots could use that footage and which tiles would be appropriate for which shots, based on 3D camera position.”

Imageworks also shot plates from the tops of buildings in New York, from angles looking up at existing elevated train bridges and from a helicopter chasing the imaginary train. “We shot around 125th Street in New York, where there is still an elevated track. Where there wasn’t track, we planned to add our CG train and tracks in the middle of the street.”

The sequence evolved as shooting continued with performers on bluescreen stages at Sony using a series of full-scale train car sets — including a full-scale destructible replica, a top roof layer and side pieces — all rigged by John Frazier’s physical effects team to simulate train motion. Edge FX puppeteers and Dan Bradley’s stunt performers collaborated with fight choreographer Dion Lam to push the limits of practical effects. “We did shots on top of the train that I never thought would be possible with the train moving,” remarked Eric Hayden. “There was a shot where Ock thrusts a CG tentacle from one side of the train through to grab Spidey on the other side. Three tentacles holding him on the train were real; the one that thrust through was CG. Another real tentacle broke the window in the front driver’s cab, coordinated with an effects gag blowing the glass. We then pulled

Doc Ock ensnares Spider-Man during the film’s finale, set inside a tumble-down waterfront warehouse. Edge FX collaborated with physical effects to create tentacle and wire effects during the showdown, which was shot on a full-scale warehouse interior set at Sony Culver Studios. Entity FX — one of a handful of visual effects subcontractors associated with the production — performed wire removals in difficult chiaroscuro lighting, creating multilayer matte paintings to rebuild backgrounds. Imageworks supplied CG tentacles for dynamic wide shots and for several expressive closeups of Ock interacting contemplatively with his mechanical appendages.



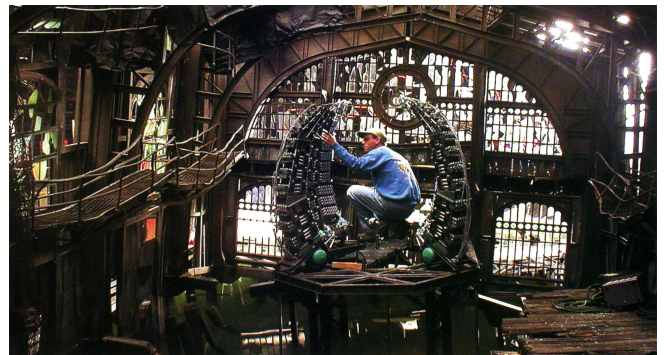
As part of the full-scale set, Neil Spisak constructed a huge fusion machine — a giant-sized version of Ock’s earlier laboratory experiment — that once again goes awry and threatens to destroy the warehouse and all metallic objects in the surrounding city. New Deal Studios constructed a spherical lighting rig, which sat in the center of the machine and emanated interactive light around the set. In postproduction, Imageworks replaced the rig with a digitally animated fusion ball, generated using nested 3D spheres covered by roiling particle effects and animated tongues of flame.

the throttle out of the train and tossed the throttle to *Spider-Man* using a real tentacle. It was downright fun — but it was also months of hard, hard work.”

The train sequence eventually featured 150 visual effects shots, and made extensive use of Imageworks’ expanded library of CG buildings, placed shot by shot to fill gaps in the plate photography. Wider angles of Ock and *Spider-Man* clinging to the hurtling train featured entirely virtual environments. One ‘spider sense’ shot, in which *Spider-Man* intuits imminent doom ahead of the runaway train, starts close-up on *Spider-Man* — a live bluescreen element — then zips to a train buffer overhanging the East River. “The spider sense shot used all of our CG environment techniques,” remarked Dan Abrams. “We tracked the bluescreen element of Tobey into plates of the Chicago el, then flew by 5,000 Maya buildings in 30 city blocks. We created boundingbox, low-rez versions of the buildings for the far distance, and rebuilt geometry of the train and the rail supports. We traveled along the track so quickly that we were able to repeat sections along the way, creating variation by building custom geometry to make the rails appear to wiggle, and procedurally varying the shapes and dimensions of the rails in the composite.” The climax of the shot featured high-resolution rail structures and pulled back to photographic textures of the East River Parkway projected into a CG model, dressed with digital traffic and flanked by high-resolution CG buildings.

Sensing the end of the line, Peter Parker removes his *Spider-Man* mask while perched on the train roof and attempts to stop the vehicle using every fiber of his superhero strength. To create the digital character — unmasked and enacting perilous feats impossible to achieve with live performers — Imageworks pursued a similar approach to modeling their virtual Ock, subjecting Tobey Maguire to motion capture, cyberscan and Light Stage scans. Whereas Ock most often wore dark sunglasses, Parker required expressive modeling of his eyes — a typically tricky area to model convincingly in a CG character. “We considered traditional CG modeling for the eyes,” remarked Scott Stokdyk. “Eventually, we came up with a way to extract information from Tobey’s real eyes, using our Light Stage imagery. We created Peter Parker’s eyes using a combination of the two techniques — traditional and image-based — and then integrated that into our new pipeline for skin, cloth and hair.”

Combinations of keyframe and motion captured facial performance communicated the intense physicality of Parker’s attempts to brace himself against the front of the runaway train. “Peter places his foot down on the train tracks and shatters all the railroad ties,” said Anthony La Molinara. “We went through that action in detail, capturing the movement of every muscle in Peter’s body and face. He’s breathing, expressive, his whole body is exerting.”

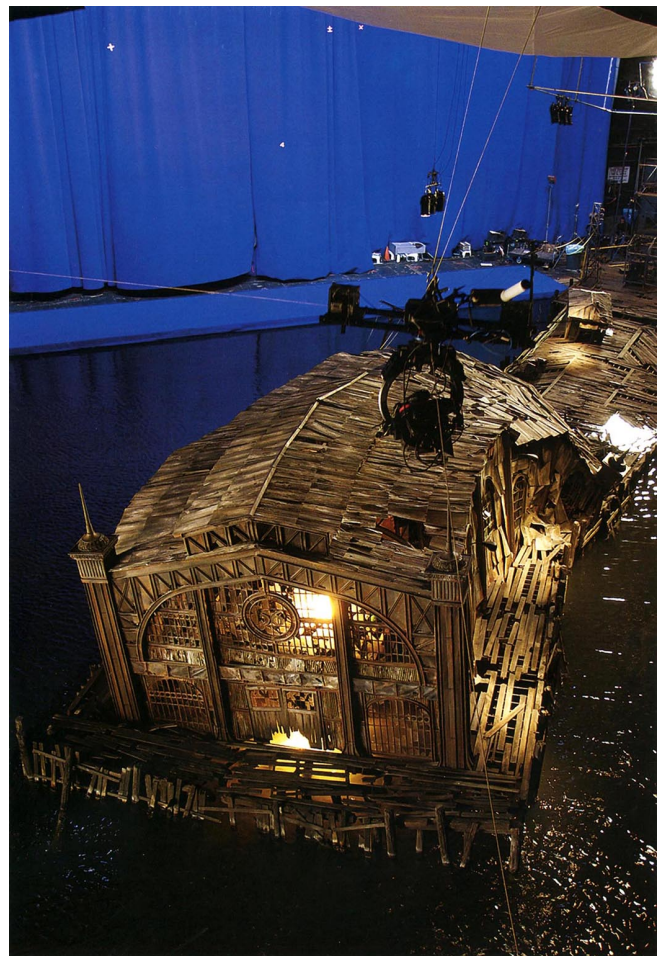


Wide shots featured 1/4-scale versions of the warehouse, built by Grant McCune Design, which were used to expand the scope of the set and facilitate implosion effects. Modelmakers assembled the miniature over a hydraulically actuated understructure located in a pit in the studio floor. Girders were cast in resin, with steel, lead and aluminum armatures allowing the structure to warp and fracture as the hydraulic understructure caused their collapse, in simulation of the implosive force of the fusion event. GMD crewmember Scott Burton attends to the miniature fusion machine.

The finale of the film unfolds after the train fight, as *Spider-Man* attempts to foil Doctor Octopus' revitalized fusion experiments and rescue Mary Jane from his laboratory lair, located in a tumble-down waterfront warehouse. Neil Spisak constructed a full-scale warehouse interior, complete with fusion machine, on Stage 30 at Sony Pictures Studios, making use of a water tank that had once been home to Esther Williams' aquatic musicals. For wide establishing shots of the fictional location, Grant McCune Design built two 1/4-scale miniature versions of the warehouse and the pier on which it was perched. "There were some potentially dangerous stunts and mechanical effects in the warehouse sequence," explained GMD miniature supervisor Monty Shook, "and the production didn't want to risk injuring any talent on set." GMD fashioned one exterior model, complete with dock and power generator, and rigged it above the tank. Another model extended the scope of the already expansive full-scale warehouse interior set, particularly for scenes of the structure's ultimate collapse into the river — shot dry-for-wet. "The dry set enabled us to shoot from positions and vantages that would have been virtually impossible in a wet environment. Control was another issue. There were large architectural structures that had to be sucked into the fusion machine — which would have been a logistical nightmare to orchestrate in water."

The production art department supplied GMD with a 1/16-scale mockup and mechanical drawings of the set. GMD translated designs into blueprints to represent the decaying iron-frame warehouse, which stood 16 feet above the water-line and extended 60 feet along the wharf. Working with John Stirber, GMD then built a hydraulically actuated understructure designed to fit into a subterranean pit inside the water tank. The scaffold supported steel platforms, on top of which GMD erected miniature and breakaway pieces. "It was a very intricate, orchestrated event," related Shook. "The warehouse was supposedly built from iron girders with a steel roof, which leant itself to a spectacular implosion as the fusion machine sucked them in. Depending on how close objects were to the event, some materials had to have a geometric collapse, others were supposed to bend in a wave of destruction radiating out from the machine."

GMD fabricated ironwork and girders in multiple patterns and then cast model pieces in resin, with steel, aluminum and lead armatures. "It was a tricky process," noted Shook. "The resin operated in a very narrow temperature range. It was rigid and brittle up to a certain temperature; but ten degrees beyond that, it turned to rubber. The lighting on set had to be constantly dimmed down after each take to



Exterior views of Doc Ock's hideaway featured another expansive 1/4-scale miniature from Grant McCune Design, also rigged to collapse. The implosion included storm effects generated using Ritter fans, adjustable air jets on the perimeter of the tank, and trapezoidal wave-makers. New Deal Studios supplied a miniature fusion machine lighting rig to create interactive light spilling from the

prevent the wharf's collapsing in a big rubber heap." Modelmakers engineered eight main beams to perform specific functions — those closer to the fusion machine designed to split at armature joints.

inside of the building as the roof collapsed, revealed in a high-angle shot. Imageworks enhanced the fusion event with digital effects, composited additional practical miniature water elements and added a digital matte painting of the New York City skyline.

To create realistic fractures in the beams, GMD introduced a gray metal tint to the liquid casting compound. Cosmetic finishing gave all surfaces a heavily rusted and corroded look.

The prefabricated miniatures took two weeks to reassemble on site at Sony. Model crews erected both miniatures on the same stage, allowing redressing of one set while the camera crew worked on the other. Referencing Imageworks previz, Dykstra, miniature unit visual effects supervisor Eric Durst and director of miniature photography Tim Angulo lit the warehouse with moonlight effects and filmed the collapse with multiple cameras, using camera speeds ranging between 48 and 72 frames per second. New Deal Studios again supplied a lighting rig to simulate the light source emanating from the fusion ball, this time built in miniature at 1/4-scale.

Imageworks composited the miniature into matte paintings of the New York skyline, tracking live greenscreen performers and animated characters into the interior set. High dynamic range image maps of the full-scale set allowed lighters and compositors flexibility in integrating Ock's animated tentacles into the warehouse interior, permitting closeup interaction and subtle animation. "All the detail we put into the CG tentacles showed up better when we had more screen space to work in," observed Scott Stokdyk. "In medium and distant shots, we had to filter down the detail."

Practical Ock tentacle effects, with wires visible in the chiaroscuro lighting of the crumbling warehouse interior, required complex digital cleanup executed by artists at Entity FX, who created multilayer digital matte paintings to rebuild backgrounds. The moody setting presented Alfred Molina with opportunities to dramatize Ock's complex relationship with his tentacles, displayed to comedic effect when he lights a cigar. "Ock was always going to light a cigar with those tentacles at some point in the movie," said Sam Raimi. "In rehearsals at Edge FX, I challenged them to grab a cigar, clip it, pluck it in his mouth as it's being lit, while another tentacle placed a stool under him, and the fourth one smashed a buzzing smoke alarm above. They pulled it off so beautifully, I re-created the scene in the movie."

All hell breaks loose in the warehouse as Ock battles *Spider-Man* and then pitches his fusion machine into the East River. QMD created a six-foot-long, 1/4-scale lifeboat — patterned after lifeboats on the *Titanic* and fabricated out of malleable copper — for shots of the boat crashing into the imploding reactor. Miniature effects also brought down the back wall of the iron warehouse, almost flattening Mary Jane. "Production tried to bring the wall down full-scale," remarked Monty Shook, "but the full-scale effect looked too controlled, so we ended up re-creating it in 1/4-scale. We built it out of a couple of hundred miniature corrugated panels to represent sheet metal siding, using three different densities of aluminum run through a corrugating machine. The metal was very soft, and had no memory at all, so it wouldn't spring back when it bent. For other areas, where they wanted less damage, we used tempered aluminum sheeting."

Imageworks composited the unmasked *Spider-Man* and Mary Jane beneath the falling wall, then swinging to safety as the pier collapses. The implosion included miniature storm effects generated

in the Sony water tank by John Stirber using Ritter fans, adjustable air jets on the perimeter of the tank, and trapezoidal wave-makers. GMD generated destruction effects for a high-angle Spydercam shot of the imploding warehouse roof. “You see the Ock machine malfunctioning, lightning bolts coming out,” related Monty Shook, “then all physical material is drawn into the hole. We used an elaborate hydraulic cable system to pull the walls and beams and girders from within. Some of the structures had substantial integrity, because they had to hold up this 16-foot-tall structure; so it needed tremendous physical force to pull it in. It was pretty violent. We did that in two takes.”

To create more turbulence in the river, New Deal Studios shot a variety of splash rigs and devices in the blacked-out Sony tank. Bowling balls, boxes of lead weights, a 55-gallon drum filled with water, and a slab of one-inch-thick steel trench plate dropped from a height and shot at 72 frames per second served to create geometric splashes. Five submerged air mortars on a sequenced timer, blasting explosions of water against a 16-foot-long splash wall, created a giant curving wave. A semicircular array of air nozzles also directed several hundred pounds of air pressure onto the water surface, creating a fan-shaped, helicopter-style disturbance. Finally, six air cannons submerged in 12 feet of water, pointed upward and released simultaneously, created a submarine-style cavitation effect.

Imageworks made use of these elements in composites of the pier collapsing and Doc Ock’s demise, as the glowing fusion ball is seen underwater, disappearing into the murk, dragging Ock by his tentacles — rendered digitally in full-frame closeup. “We went over and over how to shoot the final shot of Doc Ock,” recalled Scott Stokdyk. “Dry-for-wet photography usually works pretty well, but this was such a long camera move, we felt the best way to do it was CG because that gave us the control we needed. It ended up as our biggest CG Doc Ock shot.” Imageworks shot video of Molina enacting his final scene as animation reference. “We tried to match Alfred’s performance as closely as possible. We also studied a lot of real underwater footage. We discovered that although it might first seem that there is no specular component underwater, the specular does become visible with intense backlight; so we paid special attention to that because Alfred was rim-lit. We also added a wavy underwater hair simulation, caustics and bubbles, being careful not to obscure his face.”

The film concludes with a final bravura swing as *Spider-Man* — energized by a renewed sense of purpose and commitment to his crimefighter role — heads off to another crime scene. Lasting close to 40 seconds, the shot took off from a live-action plate of the exterior of Peter Parker’s apartment and then covered a 30-block expanse of virtually modeled skyscrapers. “We had so many issues stabilizing and integrating live-action background elements into swing shots on the first film,” Stokdyk observed, “we felt that if we spent that time working on the animation of the camera, removing restrictions on the animation, we’d get a lot more out of it. So that’s what we did. After working on CG buildings for four years, we had a pretty good idea what they should look like!”

One fictional skyscraper — two tall walls forming a U-shape trench around a central atrium — lent itself to a particularly dynamic angle plunging through the opening, leading into a street scene with teeming traffic and emergency vehicles. “We had a huge library of street props, hot dog stands, subway entrances, manholes,” recalled Dan Abrams. “There was no procedural way to dress that kind of detail, so we copied and pasted all the geometry by hand.” Technical directors developed a procedural system for animating cars, while motion captured people provided animated

pedestrians. A dozen motion capture subjects were replicated to thousands with the application of different animation cycles.

Complex action sequences and innovations required to bring the film's lead characters to life resulted in a hefty visual effects workload. The shot count nearly doubled that of the first *Spider-Man*, filling 40 minutes of screen time; and yet, shots had to be delivered in the same amount of time. Imageworks achieved the feat by employing a larger crew and a revised approach to shot production. "We worked smarter!" declared Scott Stokdyk. "Last time, John Dykstra and I visited each artist, workstation by workstation. This time, we brought everybody into one viewing environment, assembly-line fashion, viewing dailies wall-size on a 1K Texas Instruments Digital Light Processing theater projector, which we calibrated to look identical to film. Viewing color imagery that corresponded so closely to film enabled us to have far fewer film outputs and was very helpful for the artists. It made for much more timely feedback."

Throughout the making of *Spider-Man 2*, however, the integration of new technology was tempered by the true narrative needs of the story, and was guided by a visual effects supervisor whose career has been associated with innovation. "Today's latest technology becomes tomorrow's old saw," observed Dykstra. "I started out doing optical effects when there was no motion control. Then motion control came along, and that became the norm. Today, we use motion control only on a very limited basis. Technology changes constantly. Visual effects aren't about the technology we use to create the images; they are about the story that those images tell."

For Sam Raimi — who has already signed on for his third and, by all accounts, final *Spider-Man* adventure, scheduled for release in summer 2007 — the emotional context behind the spectacle remains the primary appeal of Marvel's enduring web spinner. "The audience is attracted to the humanity in the story," Raimi concluded. "That really was the most important thing — and that may have helped the effects. You really know who Peter Parker is. You really know what he wants, and how much he loves this woman. So, when *Spider-Man* goes to the rescue, the audience has all of that behind them, as opposed to simply looking at a visual effect. They want it to work, because they want to believe."

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Ghosts in the Machine

image

ARTICLE BY JODY DUNCAN

Among the most enduring works of science fiction literature is Isaac Asimov's *I, Robot*, a compilation of loosely related stories exploring the complex relationship between mechanical beings and the humans they have been created to serve. In the fifty-some years since its publication, *I, Robot* has intrigued filmmakers, but confounded adaptation attempts — even by talents as prodigious as Harlan Ellison, who crafted a never-filmed screenplay based on the book in the early 1970s.

"*I, Robot* never looked like something that could be turned into a narratively cohesive movie," noted director Alex Proyas, who at last overcame the work's inherent obstacles, "because it is made up of nine short stories that have a fairly tenuous connection. How to turn those nine random stories into a movie has always been a real challenge — even though there are a lot of fans of this book, and a lot of people have tried."

Proyas and screenwriters Jeff Vintar and Akiva Goldsman finally solved the problem of adapting *I, Robot* by not adapting it, but rather creating an altogether new story — a prequel of sorts — that would set up the rich and detailed world in which Asimov's stories existed. The idea presented itself when Proyas read Vintar's original script, *Hardwired*, which concerned a robot accused of murder. "Hardwired struck me as being very much an Asimov type of story," said Proyas. "In fact, when I read it, I wondered for a moment if it was based on an Asimov story. I felt that *Hardwired* and *I, Robot* were compatible; and when the *I, Robot* book became available, we brought the two projects together. We took the narrative gist of the *Hardwired* script and set it against the construct of Asimov's book. I like to think of our story as the tenth in the *I, Robot* collection — an introduction to this Asimov world."

The film is set in Chicago 2035, the year U.S. Robotics is rolling out millions of its new, state-of-the-art 'NS-5' robot for mass distribution — one robot for every five homes in the United States. One of them, an aberration that calls itself 'Sonny,' is suspected of murdering his creator, Dr. Alfred Lanning (James Cromwell). No devotee of robots, police detective Del Spooner (Will Smith) first hunts Sonny, then joins him in uncovering and fighting a threat that extends far beyond the murder of one man — an invasion of NS-5s gone bad, under the control of a powerful virtual intelligence.

Though initially lacking an official greenlight from Twentieth Century Fox, Proyas embraced the project wholeheartedly, refining the script with the writers, generating animatics, and developing designs with production designer Patrick Tatopoulos over a two-year period. "When Alex first came to me," Tatopoulos recalled, "he said: 'We need to design the robot first. If we don't have a robot, we don't have a movie.' So I started playing with robot concepts. One of the first things we did was look at what had been done with robots in movies before. We were most impressed with the one in *Metropolis*, which was very elegant and, in some ways, very human. We wanted to get away from what we had seen more recently in movies, such as the endoskeleton in *Terminator*. We didn't want

to go with anything that menacing because our robot, in the context of the movie, is supposed to be an object that people want to have around — in their homes, in their streets, everywhere. Our robot had to be pleasing to look at, had to be something people would be comfortable with.”

Tatopoulos found the ultimate inspiration for the Sonny/NS-5 design one day at his office, while observing his assistant at work at her iMac computer. “I thought, ‘Why don’t we approach this robot as if it is a computer of the future?’” Tatopoulos recalled. “That was something people would be comfortable with, because they’re accustomed to having computers in their homes. Essentially, this robot would be a computer on two legs.”

The iMac also inspired the idea of a translucent plastic shell covering the robot’s mechanical understructure, itself reflective of current state-of-the-art robotics. “We didn’t want pistons or big, clumsy mechanical devices,” Tatopoulos explained, “especially in the head. So we went with new technology used in artificial limbs, which is a fiber that reacts to electrical impulses. The robot would have a mechanical skeleton, covered with transparent plexiglass in the body and a more flexible silicone in the face, which could, theoretically, respond to these electrical impulses to create expression. That design allowed for human-like movement. Everything on the robot is very much like a human being — there are muscles, there are bones, and there is skin.” For the robot’s face, Proyas suggested tapping into the angel world to create a visage that was androgynous, peaceful and very pleasing to look at.

Design and articulation concepts were not limited by physical constraints, as Sonny — and all of the robots in the movie — would be computer animated. “CG is often unconvincing when it comes to creating flesh and blood creatures,” said Proyas. “But one thing it does damn well is create mechanical creatures. So it was a no-brainer to do the robots with CG. With Sonny, especially, it was all about performance and emotion — and I don’t know how we could have done that any other way.”

With Sonny’s design completed, Proyas and Tatopoulos turned to the design of the NS-5 predecessor, the NS-4. The filmmakers determined that, technology-wise, the NS-4 should fall somewhere between today’s robotics and those of the NS-5. In researching current robotics technology, Tatopoulos had learned that there already existed entirely self-contained robots. “There are robots that have no wires coming out of them, and that look anthropomorphic,” explained Tatopoulos, “with a head, chest, legs and arms. But they are quite bulky. If you push that technology 15 or 20 years into the future, they will get smaller and smaller, just as computers have done — and that was the NS-4. It’s anthropomorphic and more streamlined than what we have today, but it’s still a bit bulky. It doesn’t move as smoothly as a human being or an NS-5, and its face doesn’t move at all.”

Within the context of the film, the NS-4s are a ubiquitous presence in the near-future world, as commonplace an element of modern life as the automobile. The point is clearly made in an opening scene in which Spooner walks the streets of his down-and-dirty neighborhood, NS-4s everywhere — running errands, delivering packages, sweeping



streets and collecting trash. “One NS-4 walks down the street with a big Starbucks sign on the chest,” Tatopoulos commented, “a walking advertisement. One robot has graffiti on it, as if kids have come and sprayed it with paint. We wanted to create the sense that these robots are just a normal part of these people’s lives.” NS-4 models assigned to specific tasks, such as window washing, were nonanthropomorphic in design. “There was no reason for a window-washing robot to look anthropomorphic. Same with street-sweeping robots. The only reason a robot would be made to look like a man is if it was going to be interacting directly with people, as a way of making people comfortable with it.”

I, Robot sets an original tale about a robot accused of murder within a future world conceived by Isaac Asimov in his same-titled compilation of short stories, first published in 1950. Working from a Patrick Tatopoulos ‘NS-5’ robot design, a Digital Domain team – headed by visual effects supervisor Erik Nash and animation director Andy Jones – built and computer animated the murder suspect, Sonny, a leading character in the film. In a police station holding cell, detective Del Spooner (Will Smith) interrogates Sonny about the death of his creator, robotics pioneer Dr. Alfred Lanning.

The years-long conceptual work continued as the project entered official preproduction, which would last ten months. During that time, Proyas continued to develop animatics for virtually every scene in the film, using them to plan the production — even using them as a selling tool. “While the studio was still deciding whether or not to proceed with this movie,” recalled producer John Davis, “Alex used the animatics to cut a trailer, which was very clever of him. He came in, and said, ‘Here’s the trailer for your movie.’ And the studio people looked at it, and said, ‘We are so in.’”

The shoot, like preproduction, was on the long side, consuming nearly six months on locations and stages in Vancouver. Art department and construction crews built partial sets surrounded by massive bluescreens or greenscreens to facilitate the addition of digitally-rendered environments by Digital Domain and Weta Digital, the two primary effects vendors on the show. Senior visual effects supervisor John Nelson, in addition to orchestrating 1,000-plus effects shots in postproduction, was on set throughout the shoot to oversee the many bluescreen/greenscreen setups — all of which were aided immeasurably by an on-set virtual studio system, ‘Encodacam,’ developed by Joe Lewis at General Lift. “Encodacam enabled us to start a shot on a partial set,” explained Nelson, “and, in real time, do a camera move that moved off the set and into a digital set. On a monitor, we could see the actors in that digital set, see the extension of the camera move — all in real time. It was one of the many cutting-edge technological advances we used on this picture.”

To develop Encodacam, Lewis had combined traditional motion picture camera encoding and recording equipment — for which his company is known — with broadcast virtual set technology. Employed for many years in controlled broadcast studio environments, that technology involved mounting targets on the studio’s ceiling and walls, which enabled a computer to track, live, a moving camera and make it look as if it was moving within a virtual environment — creating the illusion of a news anchor’s or any other live subject’s presence within that environment.

Applying that technology to fast-paced motion picture production had been impractical, due to the lack of time to set up markers and calibrate the computerized camera tracking. With advances in camera recording and encoding technologies, however, Encodacam's time had come. "Encodacam was one of the coolest, most helpful things I've seen in a long time," stated Brian Van't Hul, on-set visual effects supervisor from Weta Digital. "It allowed us to key together low-rez geometry — which often came from the previz — and the actor on the bluescreen or greenscreen stage, so we could actually see them together on a separate video assist split. If the camera was moving around, we could record that motion and see the same moves on this keyed-together image of the actor in the low-rez virtual environment. It showed up on a monitor like a rough 3D composite — but done live, with all the camera moves."



Set in 2035, the film opens with a wide establishing view of Chicago. Extrapolating from existing city plans, Tatopoulos and director Alex Proyas conceived a near-future Chicago that had modernistic highrises in outlying areas and a relatively unchanged downtown district. Though the main unit never shot in the city, a small second unit spent a week there, shooting aerial plates, and photographing and lidar-scanning key buildings. Weta Digital used the second-unit material to create any number of futuristic Chicago environments, extending live-action street sets constructed and shot in Vancouver.

The benefits of the Encodacam system were many. First and foremost, it enabled actors — often adrift in a sea of green or blue — to see what the final shot would look like. "More and more these days," Van't Hul related, "movies are being shot on big greenscreen stages with minimal sets and actors who don't have a clue as to what is going on. They're told to look at a cross on a wall or to look at a tennis ball, and that's all they have to go on. It's not a very inspiring environment. This system was tremendously beneficial to the actors because, between takes on set, they could see the composited image and get a better sense of the scene, which really helped their performances."

The system also enabled the director and the camera operator to collaborate as if in a real environment. "In a primarily green environment," explained Van't Hul, "the camera operator might do a pan, for example, without knowing exactly what he is panning from or panning to. It is all a guess, and then it has to be fixed in post. With this system, the camera operator could see exactly what was happening and knew where to point the camera and how fast to pan back and forth. The director could have a relationship with the camera operator, to confer with him in real-world terms. He could say, 'If you pan a little bit over and tilt up, look what we'll see!' It allowed him to direct the camera movement, for real, on a virtual set."

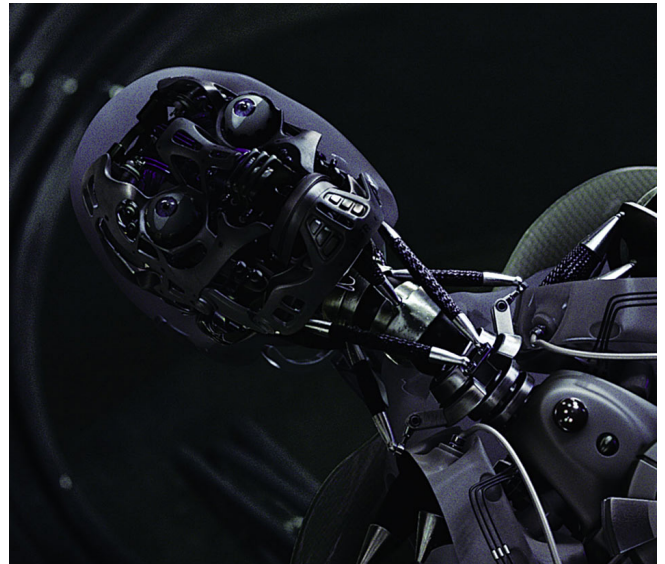
Another benefit of Encodacam was that it created keyed-together footage that editorial could cut into the film, giving the director a sense of pacing and timing in a scene many months before final effects shots would be completed. “Without it,” said Van’t Hul, “the editors get a bunch of material where the camera is panning from green onto this actor and then off of the actor to green — and they’re like, ‘Uh...okay...I don’t know what is going on.’ This gave them a bash comp they could use to do the cut.”

The film’s opening moments establish a Chicago that is futuristic, and yet familiar, with all of the city’s present landmarks and iconic buildings still in place. “A lot of futuristic movies have environments that are dazzling, but quite cold and hard to relate to,” noted John Davis. “Alex wanted to create a future that was an exciting, technologically-friendly place, rather than the alienating place we so often see in movie future worlds. The architecture is amazing, but also relatable. The cars are fantastical, but understandable. The technology all looks as if it is the next logical leap from where we are now.”

Patrick Tatopoulos’ original designs for a far more futuristic fictional city had been mandated by the story’s initial time setting of 2080, and by plans to base the production in Sydney — specifically at the Olympic Stadium, which features very bare, futuristic architecture. When the studio changed the production venue to Vancouver before the start of filming, the filmmakers were forced to rethink their vision of the city. They transplanted the story to Chicago, and moved up the time setting to 2035, enabling the production to make use of some real — if slightly modified — locations. “Eighty years in the future, everything will look quite different,” Tatopoulos noted. “Thirty years? Not so much. It made the job more interesting for me, in that I had to adapt an existing city and figure out how we could expand it to make it futuristic, but still something the audience could relate to and recognize. It was more of a challenge to integrate new buildings into the existing Chicago than it



To give the human players someone to interact with on set, actor Alan Tudyk – wearing a green suit dotted with blue tracking markers – performed all of Sonny’s scenes during principal photography. The resulting live footage also served as impeccable performance reference for Digital Domain animators when they replaced the surrogate with their computer generated robot. The final CG robot was made up of an interior mechanical structure and a translucent plastic shell – each comprised of multiple layers of rendered imagery – which were individually manipulated in composites to reflect specific lighting environments



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would have been to design an all-new city from scratch.”

The inexorable advance of technology during the years the movie was in development was another factor in changing the film’s time period. “We moved the story up a few years because every year that ticked by, technology would catch up to it,” Proyas explained. “Every few months we’d see another new robot design that was closer to the robots in the movie. So we decided that the movie couldn’t be that far into the future. The future was rapidly approaching.”

To create Chicago 2035, Proyas and Tatopoulos first looked at concepts of what the city would look like in 20 years, as envisioned by architects and city planners. Extrapolating from those city plans, the filmmakers devised a downtown Chicago that would remain essentially unchanged, with ultra-modern buildings overtaking the suburbs, where there would be available space for new construction. Tatopoulos designed buildings that reflected real-world architectural trends — such as 100-plus-story highrises made entirely of clear materials. “It’s beginning to look as if the cities of the future will develop with whole buildings being transparent, so that nothing is hidden,” stated Tatopoulos. “We are seeing that in construction now, and it’s a real direction for future building. Transparent buildings also tied into the translucent look of the robots.”

The film’s Chicago-set scenes belie the fact that a main unit camera never rolled in Chicago. A very small second unit — headed by digital effects supervisor John Berton — did spend a week in the city, shooting aerial plates, photographing stills to use as textures, and doing lidar scans on seven key buildings, all of which contributed to digital city environments created by Weta Digital. “We relied on a mix of techniques for creating the Chicago environments,” said Weta visual effects supervisor Joe Letteri. “We took the 2D photography that had been shot by the Chicago unit and used it for matte painting elements or projection matte painting. We also had lidar data for all of the landmark buildings in Chicago, which gave us high-rez geometric models for anything close in.”

The first reveal of the city cranes down from Weta’s wide establishing view to a street bustling with people and NS-4s. Live-action for the scene was shot on a street set, with proxy robot performers acting among extras to ensure accurate eyelines, spacing and interaction with the human characters. “Alex likes to work with real things and real people,” John Nelson said, “so, even though we had to move really fast, we always rehearsed with the proxies and shot takes with the proxies. For post purposes, the proxies wore green suits with blue tracking markers, or blue suits with green tracking markers, or just gray suits — so we were covered in any lighting situation.” All of the proxy performers were trained in robotic movement by Paul Mercurio, Proyas’ longtime friend, and the star of *Strictly Ballroom*.

The absence of many of the film’s characters — and, in the case of Sonny, a leading character — on the set meant that, instead of the typical one setup per shot, *I, Robot* required five setups for every shot involving a robot. “Fortunately,” stated Nelson, “we got very fast at doing those five setups,

and a translucent plastic shell — each comprised of multiple layers of rendered imagery — which were individually manipulated in composites to reflect specific lighting environments performed all of Sonny’s scenes during principal photography. The resulting live footage also served as impeccable performance reference for Digital Domain animators when they replaced the surrogate with their computer generated robot. The final CG robot was made up of an interior mechanical structure and a translucent plastic shell — each comprised of multiple layers of rendered imagery — which were individually manipulated in composites to reflect specific lighting environments

because each one was absolutely necessary. We had to rehearse with the proxy to give the actors and the cameraman a sense of the scene. We had to shoot with the proxy to get animation reference. We had to shoot a pass without the proxy but with the actors so that Weta or Digital Domain wouldn't have to take out a guy in a green suit in every single shot. We had to shoot a plate without the actors or the proxies to give them a clean environment they could use for cleanup purposes. And we had to shoot a take with a full-scale prop robot in the scene."

This last was necessary because the proxies — made of flesh and bone rather than high-tech metal and plastics — were useless as lighting reference. To provide that reference, Tatopoulos and his crew constructed two full-size, positionable robots. "We designed them in 3D," said Tatopoulos, "then had an output of those designs made to build each part of the robots. After assembly, they were used on set for virtually every scene. Even as we continued to work in postproduction, for every shot they would display the practical robot next to the CGI robot, to make sure they matched." Additional lighting reference was achieved by shooting gray and chrome ball passes. A final pass of high-resolution stills recorded a range of exposure from the brightest light to the deepest shadow and were used in the image-based rendering of the photoreal CG robot.

When all of the reference and live-action plates were delivered to Weta or Digital Domain, the effects teams found that, in most cases — particularly in highly interactive scenes — the plates including the green-suited proxies were better takes than those in the actor-only plates. The result was that for hundreds of shots, digital artists not only had to incorporate the computer animated robots, they also had to do painstaking cleanup on the plates. "The NS-5s have a very narrow abdomen that tapers down to a three-inch-diameter spinal cord," said Nelson. "The design made it clear that there was no man in a suit playing the robot — which had been important to Alex and Patrick — but it also meant that the NS-5s were very spindly and had much smaller silhouettes than the human proxies. So whenever we had to use a proxy pass — which I would estimate we did at least 50 percent of the time — we would have to paint out the parts of the proxy that showed around the robot and occluded the background. And we had to do that without benefit of clean motion control passes, because this movie had only one motion control shot — out of more than 1,000 effects shots."

Charged with the creation of Sonny, Digital Domain executed proxy-removal in more than half of its shots, filling in backgrounds occluded by actor Alan Tudyk, who portrayed Sonny on set. Digital Domain relied on a variety of techniques to do the cleanup work, determining which to use on a shot by shot basis. "Sometimes we did fairly straightforward split-screens," recalled Digital Domain visual effects supervisor Erik Nash, "and sometimes we projected a clean plate back onto reconstructed set geometry, then digitally rephotographed through the tracked camera of the clean plate — which was fairly innovative."



Production visual effects supervisor John Nelson oversaw effects concerns during the long shoot, and also orchestrated the work coming out of Digital Domain, Weta Digital and other vendors in postproduction. Among the post chores was digitally extending partial live-action sets, or creating them entirely in CG. For a scene in which Spooner and behaviorist Dr. Susan Calvin (Bridget Moynahan) look for Sonny amongst ranks of identical NS-5s on a U.S. Robotics factory floor, Proyas filmed the actors on a nearly empty greenscreen stage. Digital Domain added a 3D factory environment populated with 1,000 complete robots.



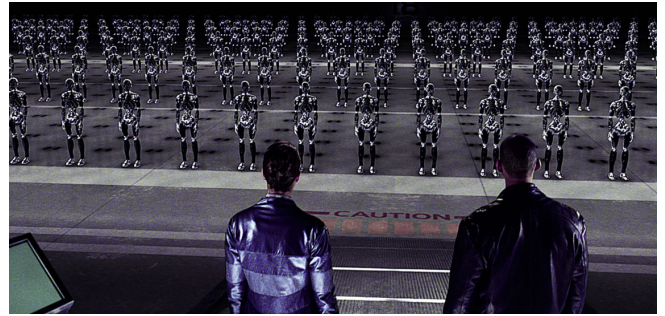
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The latter technique was made possible by the special properties of Nuke, Digital Domain's compositing package. "Nuke has a very robust way of projecting imagery onto geometry," explained digital effects supervisor Jonathan Egstad. "In the area that we needed to clean up, we would re-create the geometry occluded by Alan's body and then project textures onto it — textures that came from another part of the plate or from alternate takes. To get that clean texture, we would rephotograph it from a lock-off — so the image would be stabilized — and we'd get a nice clean texture, at 4K resolution. All of our shots were tracked very accurately, which allowed us to project those textures onto the virtual set. It was a 3D approach to reconstruction, rather than a traditional 2D approach. We had about 35 compositors using Nuke to do this cleanup work over a ten-month period — and I don't think we could have done it with any other compositing package."

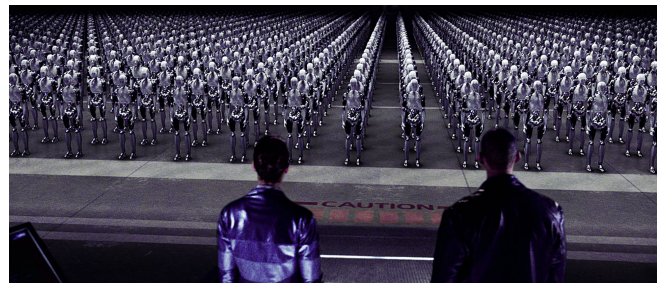
Cleanup was an issue for Weta Digital in its opening Spooner's neighborhood scene, due to the intermingling of large numbers of robot proxies within crowds of people. "Those shots had hundreds of extras," explained Brian Van't Hul, "and without the proxies, they didn't always leave the correct gaps for the robots. We'd do two or three rehearsals with the green guys; and then we'd pull them out and shoot a take — but we would find that people had walked too fast or too close together, and we couldn't fit our robots into their midst. The actor performances in the proxy plates were usually better, as well."

"One of the lessons we had learned with Gollum in *Lord of the Rings* was that when real actors act with real actors, they give a real performance. When you take that real actor away, and say, 'Okay, now just pretend that guy is there and give that same performance,' it doesn't have the same energy. Interaction between the live people and the robots was always better in plates that had the proxies."

Proxies were never more crucial than in shots in which a robot would come in physical contact with an actor — most often, Will Smith. In the neighborhood scene, Spooner bumps into an NS-4,



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shouldering him slightly. “They shot it with and without the stand-in,” said Van’t Hul, “and the one with the stand-in was the good, solid hit that made it look real. So we used that plate and painted out the stand-in.” In the same scene, Spooner chases an NS-4 he believes has snatched a woman’s purse, tackling the robot to the ground. “For Will to do that alone, without a proxy there, would have looked ridiculous. With the stand-in there to actually tackle, it looked real — because Will was really struggling, really being pushed around by a physical force, his clothes really being wrinkled by hands. Whenever we had that kind of physical interaction, we would paint out the proxy and put our robot where he was, matching the contact point precisely.”

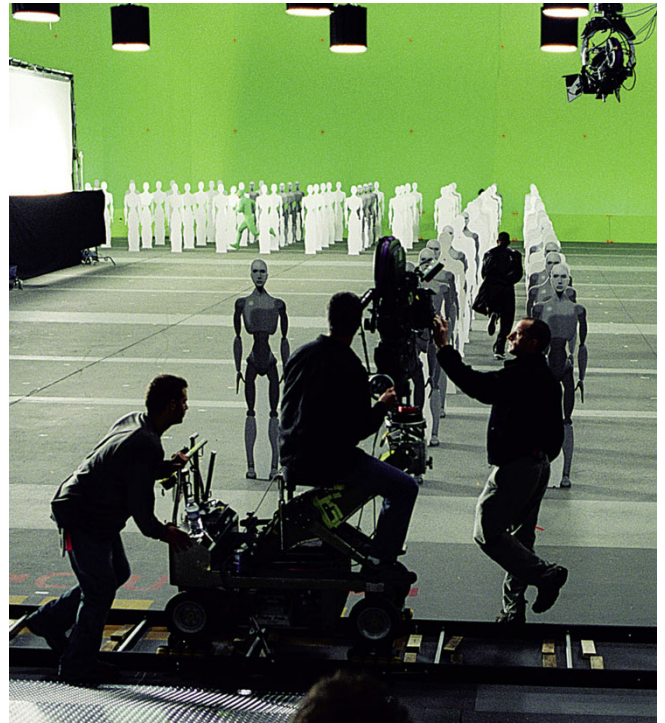


To flush out Sonny – a more emotionally evolved machine than his fellow NS-5s – Spooner points a gun at the heads of the robots on the factory floor, looking for the one that will flinch. On the minimal stage set, crews positioned tennis balls at the height of the robot heads to ensure proper alignment of Will Smith’s interactions with the CG NS-5s in the final shots.

Spooner releases the robot when its owner angrily informs him that the NS-4 was only delivering her asthma medication. Again, the actor performances in the plate featuring the robot stand-in in the background were better than those in the clean plate, and Weta had to remove the green-suited performer — a task made more challenging when Proyas asked that the NS-4 be placed in a different position to camera. “It was a bit tricky to paint out the stand-in and reposition the robot,” said Van’t Hul, “because there was a crowd of people walking back and forth behind the stand-in — but, of course, they didn’t walk back and forth the same way in the clean plate as they did in the proxy plate. So our paint department actually had to re-animate bits of heads and arms from previous frames and patch them through the area. They essentially became 2D animators, dealing with moving faces, moving hair, moving clothing and all this stuff that had to be stolen from other takes or from previous frames and re-animated. It was a very big deal. In shots like that, the people in the paint and roto departments become your best friends.”

Weta built the NS-4s populating Spooner’s neighborhood from the Tatopoulos design, then controlled them through Massive, the artificial intelligence crowd system that had created vast armies for *The Lord of the Rings*. “Because there were so many different types of NS-4s seen in Spooner’s neighborhood,” explained Joe Letteri, “we wanted a lot of variation in their actions. Some were personal assistants, others were delivery robots, others served a number of different purposes. So we keyframe-animated a lot of different behaviors for the NS-4s. Then we took all of that keyframe animation and fed it into Massive, populating the scene with a certain number of each of these different types of NS-4s.”

Spooner is summoned to the 108-story skyscraper housing U.S. Robotics, where its preeminent scientist, Lanning, has jumped — or been pushed — to his death. The USR building, a central setting, would be realized through practical sets and digital extensions by Weta and Digital Domain, both of which worked from detailed schematics and a 3D concept model provided by the art department. “We did a ton of work on the 3D model,” said Erik Nash, “because it had been created for production purposes, not for the purposes of creating a photoreal virtual environment. It gave us the broad strokes and the general relationship of everything; but it was not ready to use in the final shots. We took the model further, applying low-rez textures to all the surfaces; and then we handed it off to Weta so that they could refine it for their needs.”



Similarly, to maintain appropriate spatial relationships between the human character and the CG machines, crews positioned robot cutouts on the stage for shots of Spooner running through the rows of NS-5s.

Spooner's investigation of the building and Lanning's lab reveals the presence of Sonny, a very special NS-5 that immediately becomes the police detective's number one 'robot of interest' in the possible murder. Either through Lanning's experiments or through inevitable programming anomalies — the 'ghosts in the machine' of which Lanning had often warned — Sonny possesses a greater emotional capacity than his robotic brethren, and even has the ability to dream.

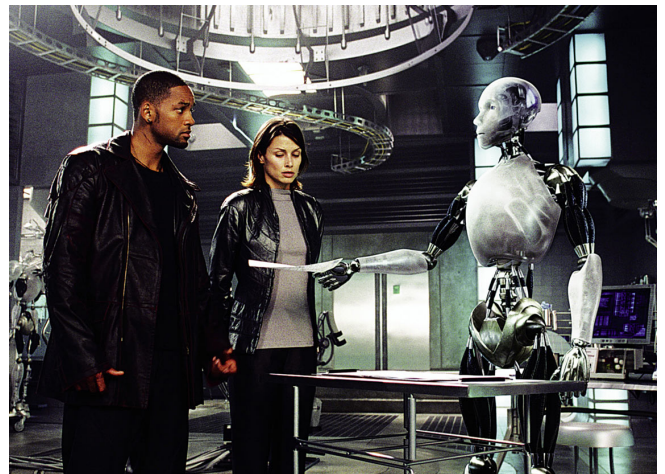
Before learning of the technique his friend Peter Jackson was using for the character of Gollum in *The Lord of the Rings* — filming actor Andy Serkis on the set, then replacing him with the computer generated character — Proyas came to a similar conclusion as to how he would create his emotionally-imbuéd robot. Actor Alan Tudyk would perform all of Sonny's scenes on the set. Then, in postproduction, animators at Digital Domain — under the artistic guidance of animation director Andy Jones — would match that performance through keyframe animation, and replace the actor with their CG Sonny.

To take full advantage of Tudyk's presence on set, the visual effects team set up two high-definition video cameras at opposing angles from the motion picture camera, each focused close on the actor's face. "We had the taking angle of the lens of the film camera," John Nelson explained, "and we'd slate it with smart slates so that the video cameras would be in sync. From that we could give the animators closeups of Alan's face from different angles. Instead of trying to do some kind of motion capture on his face, the animator could just see what the face was doing — from a variety of angles — and match it."

Before the animators could begin that assignment, however, Digital Domain — a newcomer to 3D character animation for feature films — first had to set up a character pipeline. "Digital Domain hadn't done a big character animation show before," noted Andy Jones, who had helmed the animation for



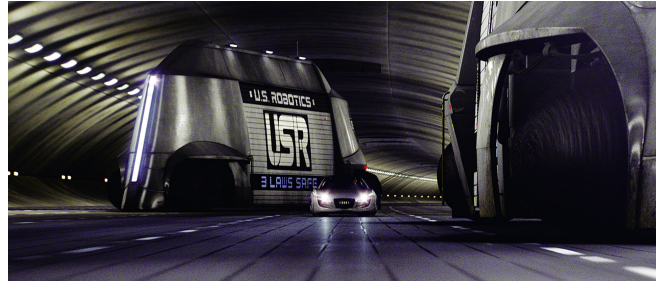
At U.S. Robotics, Sonny draws a cryptic picture from one of his dreams to show to Spooner and Calvin. Proyas captured the scene with Tudyk and the actors; then, Digital Domain replaced Tudyk with its CG Sonny. An ongoing challenge in all of the shots with Sonny was replacing areas of background occluded by Tudyk's body, the silhouette of which was considerably larger than the robot's. While 2D paint cleanup worked in some shots, others required Digital Domain artists to project textures taken from alternate takes or other areas of the frame onto re-created 3D set geometry.



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groundbreaking projects such as *Final Fantasy* and *Animatrix*, “so that all had to be set up specifically for *I, Robot* — which was a huge show. We had a total of 520 shots for this movie, and 90 percent of them were character animation shots.” Steve Preeg — who had been an integral member of the Gollum team at Weta — set up Digital Domain’s character pipeline for *I, Robot*.

Modeling lead Wayne Kennedy saw to the building of the digital Sonny model, scanning the maquette built by Tatopoulos, then extrapolating from that initial design to add more mechanics in the head and chest, per Proyas’ request. Sonny modeling was not far along when all involved realized a slight modification in the robot’s design was necessary. “We found out early on that we needed to change the shoulders,” remarked Jones. “Patrick’s design had ball joints at the shoulders, and no clavicle. In doing some of our animation tests, we realized that was going to create a big mobility problem. We needed more shoulder movement, especially for the superhuman kinds of actions the robots would have to do. So we cut in the chest shell piece and built a socket joint in his shoulder to give us a wider range of movement.”



Weta Digital provided effects for an extended chase sequence in which Spooner is cornered by U.S. Robotics transporter vehicles in Chicago’s high-tech, underground freeway system. Weta computer generated the tunnel environment and transporters, integrating them with greenscreen and live-action footage of Will Smith or his stunt double in a futuristic Audi. Patrick Tatopoulos and Alex Proyas worked with Audi to design and construct Spooner’s car, which – like all of the vehicles in the production – had spherical wheels to enable all-axis movement.

To accurately animate the character, Jones, Sonny animation lead Matt Hackett and a team of animators first had to determine the physical properties of the robot’s mechanical skeleton and translucent shell. A problem in the robot shell concept — which would dog the visual effects teams throughout the project — was that the way it looked was in direct opposition to the way it had to behave. “We figured out right away that we would need something that behaved like real skin,” said Jones, “but looked very different, like a plastic or silicone that would be hard in some areas but softer in others. The big challenge was how to get organic, lifelike, fluid movement out of something made of plastic and metal. Alex wanted Sonny to be very robotic and mechanical in its look — so that the audience would see it was not a human in a suit or a compositing trick of mapping a person’s face to a CG body — but also wanted him to move like a human being. Sonny also had to be pleasing to watch, because he’s a sympathetic character. To get all of these characteristics in this one animated character was a huge challenge.”

In order to facilitate fluid, organic movement in the face, animation tools lead Erick Miller devised a set of sliders and a blend shape tool that executed curved, rather than linear, transitions as animators moved from shape to shape. The video reference of Alan Tudyk’s performance — displayed at their workstations — gave animators impeccable animation reference; however, differences in the facial structures of the robot and the actor made one-to-one matching impossible. “We couldn’t match Alan’s face exactly,” explained Jones, “down to the movements of the lips or the brow positions, because of their very different facial structures. The topology of Sonny’s face was much more smooth and simple than Alan’s complex human face, with all the lines and everything. Sonny didn’t really have brows, for example — just a brow ridge. So we

couldn't exactly match the performance; but we could make the emotional impact of the performances the same, and that's what mattered to Alex. When he looked at Sonny and looked at Alan, he wanted to get the same emotional read. There was a lot of back and forth to figure out how to translate what Alan had done in his performance to Sonny's performance."

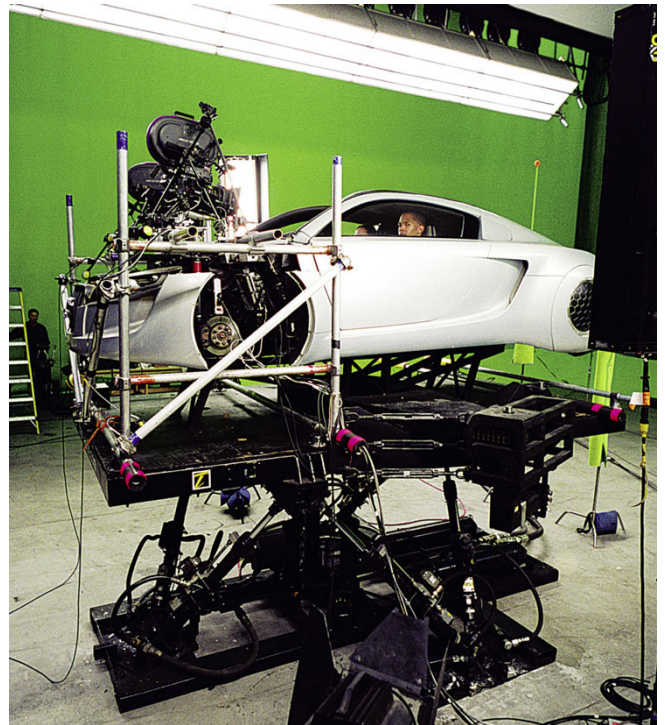
Though Proyas had done no on-set motion capture with Tudyk, production scheduled three motion capture sessions — two in Vancouver, and a third in Los Angeles — to provide the raw data for Sonny's body animation. During these sessions, Digital Domain and a team from Motion Analysis captured Tudyk going through all the actions he had performed on set. "We captured Alan walking to a door and opening it," said Jones, "we captured general walk and run cycles. We went through the whole movie, scene by scene, and captured all of his actions, which we found to be very useful." Keyframed tweaks brought out a subtle robotic movement to Tudyk's motion captured performance. Another performer was motion captured to provide animation data for all of the other NS-5s in the movie, which would behave in a slightly more robotic manner than Sonny, with simpler facial animation and stiffer body movement.

Just as disparities in the robot and actor facial structures had precluded one-to-one matching in the facial animation, their different physicalities required some tweaking of the human-based motion capture when it was applied to the robotic form. "The most noticeable difference was in the hips," observed Jones. "Because the robot's hips were so much more narrow than the performer's, they would pick up a lot more motion and swing around too much as he walked. We had to go in and tone that down; but, overall, it was a pretty smooth transfer from the motion capture to the robot."

While Jones and his team of animators concentrated on performance, Erik Nash and his crew focused on the look of the character. "Andy was the keeper of emotion," Nash related, "and my job was to keep the robot looking real. Sometimes, those two things were in direct conflict, and we would have a tug of war between reading the emotion and making it look real. It was one of the things that Alex was most concerned about. He knew that if Sonny ever stopped looking real, stopped looking like a physical object that you could reach out and touch, it wouldn't matter how well the emotion played — he'd lose the audience."



NS-5 robots emerge from the transporters to attack Spooner's car. Weta used Digital Domain's Sonny model as the basis for its NS-5, but implemented its own shading and rendering techniques to achieve the final shots.



For closeups of Will Smith inside the spinning and banking car, special effects supervisor Mike Vezina mounted a practical Audi shell on a five-axis mover and turntable rig, which was photographed against greenscreen. Weta composited the greenscreen footage into its CG tunnel environment, detailed with rows of closely spaced lights to impart a sense of high speed, and architectural features to emphasize scale.

The robot's translucent shell was one of the most difficult looks to achieve, especially since its appearance changed, depending upon lighting scenarios and narrative intent. The shell on the 'good' robots would be opaque, obscuring their mechanical understructures and making them look more benign. 'Bad' robots, in contrast, would appear more transparent — lit internally with a red 'uplink' light — revealing the menacing heavy metal underneath.

Reference footage of the full-size lighting stand-in helped to determine the look of the shell from scene to scene, but was of less use as the robot's look evolved in postproduction. "The lighting stand-in had been made out of all the appropriate materials," said Nash, "but one significant difference was that its translucent shell pieces were all rigid. To give our robot more flexibility, we created a shell that looked like a flexible version of that plastic — which gave it a different look. As the character evolved, we were able to rely less and less on the lighting reference of the stand-in; and, eventually, we stopped looking at it all together. We just had to judge the realism of the character shot to shot, relying on years of experience in dealing with photoreal CG images."

Digital Domain look development lead John Hewitt established the lighting of the robot, emulating subsurface scattering techniques — which create the look of light bouncing through skin — to achieve the translucent appearance of the shell. "Subsurface scattering is a fairly time-intensive process," remarked Jonathan Egstad, "and a very expensive proposition. We found it was better for us to simulate subsurface scattering with this material. Since it wasn't really human skin it would have needed a different type of subsurface scattering anyway. So we came up with a hybrid solution that was 50 percent rendering and 50 percent compos-iting, which gave us greater control over the look of the shell from shot to shot."

The robot's shell and mechanics were each made up of 17 rendered layers, stored in two files via Open EXR, a file format developed by Industrial Light & Magic. "Open EXR was a significant improvement," observed Egstad, "because it allowed us to put together all of those layers without a massive number of file readers." Robot assembly was a function of 'Make-Bot,' a compositing script in Nuke. Subscripts, called gizmos, were analogous to control panels the user would employ to manipulate the shell and mech layers. "Make-Bot put together all the pieces of the robot; and then the gizmos gave compositors controls for color correction, for manipulating transparency levels, for lighting and so on. We thought of Make-Bot as the second half of the shader pipeline."

Sonny is first seen in action when he escapes the lab, jumping out a window, landing in the atrium below, and running out onto a large plaza. Live-action of Spooner chasing Sonny through the plaza was shot on a parking lot in Vancouver. "We built a platform that Will stepped onto," commented John Nelson, "and surrounded the parking lot with the largest bluescreen I've ever used — 270 degrees of bluescreen on a 90 foot wall." Weta created the entire USR plaza virtually, populating it with Massive-controlled crowds of NS-4 robots. "We used terrain adaptations so that the robots could follow the stairs and make their way around the plaza," explained Joe Letteri. "We also put in stand-in objects through Massive, so that the robots would walk around and avoid the real people in the plate."

Spooner and USR behaviorist Dr. Susan Calvin (Bridget Moynahan) find Sonny at the USR manufacturing plant, hiding amongst thousands of other NS-5s on the factory floor. This location,

too, existed primarily as a virtual set, created by Digital Domain. “We had a fairly large stage space for the factory floor,” said Erik Nash, “but it was only half as big as the space would be in the movie. There was one partial wall there, where Spooner and Calvin enter the set, and we painted the floor. But looking in every other direction, it was all greenscreen. We built a big CG set, based on concept sketches that Patrick Tatopoulos delivered to us.”

Digital Domain filled its virtual factory set with row upon row of digital NS-5s, incorporating lighting that director of photography Simon Duggan had used on the greenscreen stage. “It was difficult for Simon,” noted Nash, “because he had to light this big green room, not knowing what the lighting scheme ultimately would be in the virtual set. So he lit for Will and Bridget, and we just worked around that lighting. We had to light the robots in a way that would make them look good and appropriately mysterious, yet match the lighting on Will and Bridget sufficiently to make them look as if they existed in the same space.”

Sonny is trapped in a net while trying to scale the exterior wall of the plant. The holding cell scene that follows, in which Spooner interrogates Sonny for the first time, was one of the most difficult animation assignments, as Sonny reveals a wide range of emotion in the scene. “Sonny talks quite a bit throughout the movie,” said Andy Jones, “but the holding cell was his biggest speaking scene — and it was the closest to Alex’s heart, in terms of performance. It is the height of Sonny animation, the first time you see him talk and the first time you really get a sense of who he is.”

As always, Alan Tudyk performed the scene with Will Smith in rehearsals. When cameras rolled, however, production put a monitor on a C-stand at the end of the holding cell table and piped in Tudyk’s performance from off-camera. “This scene had a lot of dolly camera moves,” explained Nash, “so it was going to be very difficult to cover up Alan in the green suit — but we still had to give Will something to relate to. So we put up this screen, which was small enough that it could be covered up with Sonny’s head when we put him in the scene.”

The talky holding cell scene required facial animators to synchronize Sonny’s lip and mouth movement to Tudyk’s, referencing the multiple closeup video views. “There’s so much complexity and detail in how a human’s lips move,” noted Jones, “it was a difficult thing to match exactly. Early on, we exaggerated the lip-sync movement, playing it as if the robot couldn’t quite nail the smooth, complex lip movement of a human. But that didn’t work. It just looked like the lip sync was off. Alex felt it needed to be as perfect a match to Alan’s as possible.” Sonny’s expressive eyes were a powerful component to the robot’s performance in the holding cell scene, and throughout the film. To make Sonny’s eyes look as human as possible, Digital Domain gave them a wet sheen — justified as a mechanical lubricating oil — and devised refraction and reflection tricks to give them depth.



In another Weta sequence, an army of rogue NS-5s destroys NS-4 predecessors stored at an industrial area. Working under the guidance of visual effects supervisor Joe Letteri, Weta artists incorporated hundreds of NS-4s and NS-5s – animated either through keyframing or through Massive, the company’s in-house crowd creation system – into live-action plates, and extended the live set with a digital wasteland representing the dry bed of a receding Lake Michigan.

Spooner continues his investigation at Lanning's house, which is destroyed by a giant demolition robot while the detective is still inside. Every shot of the house destruction was achieved through miniature photography, which Rainmaker Digital Pictures — under the visual effects supervision of Dale Fay — combined with live-action elements, CG dust and debris elements, and a computer generated 'demobot.' "We had models of Lanning's house ranging from 1/4-scale to 1/6-scale," said John Nelson, "all prescored to collapse and break apart."

Rainmaker would also composite its digital demolition robot into live-action scenes. For an initial shot of the robot's massive appendage smashing through the house interior, special effects supervisor Mike Vezina and his crew built bottom- and top-level hallways and a connecting staircase on a shaker rig. "We built that whole set on a platform that was about 30-by-30 feet," said Vezina. "We lifted the platform and floated it on a set of air bags, which gave us about 18 inches of travel. Then, on all four corners, we mounted air rams in two directions. We could isolate each ram and shake the floor in whichever direction the robot was hitting the house. If his big claw swiped from right to left, we could make the floor shake from right to left, giving Will Smith something to play against." Drop bags mounted into the stage ceiling at intervals of four feet released lightweight foam and wood debris onto the actor as he ran the length of the shaking hallways.

In addition to creating a CG demobot 'claw' for the initial demolition shot, Rainmaker shot a steel and plexiglass miniature of the robot — weighing 400 pounds and operated by a team of six via a custom motion control rig — to interact with the collapsing house miniatures and to integrate with the live-action footage. "It was a very dynamic situation," Dale Fay observed. "We were matching very specific cues and motions from the live-action — but two to two-and-a-half times faster, shooting at up to 66 frames per second, combining motion control and puppeteered action. Trying to orchestrate all of the variables within such tight tolerances was quite frenzied at times; but the final result was well worth the effort. The demobot interaction with the breakaway miniature set yielded amazing footage."



The NS-4 massacre triggers an all-out uprising, as thousands of NS-5s – under the control of a mysterious virtual intelligence – emerge from vehicles and march through the streets of Chicago. Weta created a number of all-digital shots for the city invasion sequence, which featured Massive-controlled robots within virtual environments. For closeup and midground buildings, Weta mixed and matched geometry from lidar scans to create a number of high-resolution structures. Background buildings were created through matte painting techniques.

As the sequence continues, the demolition robot rips up a section of floor in front of Spooner. Vezina's crew hinged a floor set piece at three points and mounted it to a hydraulic rig to make it buckle, then drop away as a stuntman on a cable jumped over it. "We did the landing with Will," said Vezina, "and for that, we had another little piece of set — a predressed piece of floor that was dropped down to make a kind of slide that deposits the character onto the lower level of the house. We had Will pendulum his way in the last four feet, hitting the front portion of it and then sliding down to the bottom." Now at the ground level of the house, Spooner executes a flying kick at the front door and essentially surfs his way out of the collapsing structure. Vezina's crew mounted a door on a set of cables and wired a stuntman to it to perform the surfing action. To get closer shots

of Will Smith, the crew put the door on a five-axis gimbal and shot the actor riding the device against greenscreen.

Still reeling from his narrow escape from Lanning's house, Spooner is engaged in a high-speed chase in Chicago's underground freeway system, pursued by rogue NS-5s in USR trucks. The automated freeway system and vehicles with spherical, all-axis wheels were among the most futuristic elements of the movie, and allowed for an unusually dynamic chase sequence. "All of the traffic in the tunnel is computer controlled," explained Patrick Tatopoulos. "When you enter this ten-lanes-wide freeway, the computer takes over, and the car drives on its own, automatically fitting into the flow of traffic. The computer keeps track of all the cars, keeps a constant distance between them even as new cars enter and other cars exit — so even though all the cars are traveling at about 200 miles per hour, it is perfectly safe. If a car in the middle has to exit, all of the cars automatically shift to accommodate it.

"The ball wheels came from the idea of cars being able to move not only forward, but also sideways, laterally, to facilitate this always-shifting traffic pattern. The concept is that the ball wheel is inside a socket, held there by an electromagnetic impulse; so there is no friction, no axle, and the ball can move in any direction."

Production formed an alliance with Audi, which would provide Spooner's hero car and others in the film. "When I learned that Audi was working with us," Tatopoulos recalled, "my biggest fear was that when I sent off this design to them, they'd laugh at us. 'What are you guys doing? We're not putting ball wheels on an Audi!' But they really digged it. We worked in collaboration with their design team to develop the ball-wheel concept and incorporate it with an Audi model that's coming out in the next two or three years." Mike Vezina's crew modified the Audi somewhat to make it more filmmaking-friendly. All together, the production built a dozen ball-wheeled practical Audis for the picture. "All of the cars actually moved on their normal wheels. We just rigged dummy ball wheels on the outside and made them look as if they were moving."

To get spinning and banking moves in closeups of Smith in his car during the tunnel chase, the crew shot the Audi shell against greenscreen, mounted to a five-axis mover and turntable engineered by Vezina. A scan of the Audi provided Weta with the basis for its digital car, seen in wide shots in the tunnel chase, maneuvering amongst digital USR trucks. Weta also built a variety of digital cars for other scenes in the movie, augmenting the dozen practical ball-wheeled vehicles. "For the vehicles," explained Joe Letteri, "we took Patrick's basic designs and kit-bashed them to make more varieties. We started off with half a dozen approved designs, and we took off from those, modifying them and mixing and matching pieces to create enough variety to populate the scenes."



For both Digital Domain and Weta Digital, one of the artistic conundrums of the show was that the NS-5 had to be tremendously warm and appealing in the Sonny scenes, yet cold and menacing in the robot war finale. Lighting that emphasized or de-emphasized the mechanical understructure differentiated between 'good' and 'bad' robots, as did a red uplink light – signaling their control by an outside source – emanating from bad-robot interiors.

Weta created the entire tunnel environment for the chase scene, both for wide views and as backgrounds for the greenscreen Audi shell footage. “The tunnel was a tough environment to build,” stated Letteri. “Just getting enough details to clue people in to its size became the hardest part. We went through a lot of iterations to develop tunnel architecture, fans and doorways — anything that would create a sense of the scale.” To help sell the illusion of cars moving through the tunnel at very high speeds, Weta dressed the tunnel with row upon row of closely-spaced lights. “We wound up with thousands of lights because the vehicles were moving at 200 miles per hour, and any one shot covered a huge amount of territory. It was an enormous setup to texture all of that and light it.”

As the chase progresses, NS-5s emerge from the USR trucks and launch an all-out attack on Spooner’s car. The shots fell to Weta, which started with Digital Domain’s geometric NS-5 model. “Digital Domain had built the puppet and the facial rigs and the geometry,” said Letteri, “and they sent all of that to us. But because they have their own lighting and shading and compositing pipeline, and we have ours, we developed our own set of shaders and our own technique for getting the final look of the NS-5s.” Rather than the half-rendering/half-compositing technique Digital Domain had devised to create the look of the robot, Weta did full-on subsurface scattering, baking in as much of the robot’s look as possible in the render. “Like we had on Gollum, we got the subsurface effect in the lighting. But because of the translucency of the robot, we had to break the renders down into a handful of layers. We did some relighting as we assembled those layers in the comp, but we always tried to get the lighting correct in the rendering to begin with.”

Spooner’s frantic maneuvers to shake the NS-5s climbing atop his vehicle lead to his crashing and flipping the car. Mike Vezina’s crew built a hydraulic rig to flip the Audi 180 degrees, with Will Smith inside it. “Once we had the car going onto its roof with Will inside,” said Vezina, “we cut to exterior location work, where we dragged a more beat-up version of the car upside-down into a set of scaffolding, then released it and crashed it into a pillar.” Subsequent shots of a pinned NS-5 flipping the car over and flinging it toward Spooner made use of the hydraulic rig and an endless cable and rail



Homicide lieutenant John Bergin (Chi McBride) fires on NS-5s as they attack police headquarters. Apart from the Digital Domain robots, the police station invasion was primarily a practical event, with Mike Vezina and the special effects crew ratcheting desks and rigging bullet hits on the set. Some shots of CG robots being hit with gunfire utilized rag-doll simulations to make them collapse and fall. A targeting system in Maya enabled animators to determine the gunfire’s trajectory and velocity.



When Spooner learns that the robot assault is being orchestrated by VIKI – U.S. Robotics’ Virtual Interactive Kinetic Intelligence – he fights off swarms of NS-5s at the headquarters’ ‘VIKI Level’ to inject the computer’s core with nanites, and thus destroy her. Smith and Moynahan and a crew of stunt robot proxies performed the fight scene on a wagon-wheel-shaped structure, elevated eight feet above the stage floor and surrounded by green on all sides. Digital Domain replaced the proxies with computer

system to tow and crash the car into a second breakaway pillar. “This was done with Will, so we had to be able to control it completely. Someone could put the brakes on the tow vehicle, in case Will didn’t get out of the way in time.”

animated NS-5s, and extended the live-action set with a digital VIKI environment.

To solve the mystery of robots gone awry, Spooner follows Lanning’s posthumous clues to an industrial area — a dry bed section of the receding Lake Michigan — where he witnesses an all-out massacre as an army of NS-5s destroys the NS-4s stored there. The sequence fell to Weta, which incorporated hundreds of Massive and keyframe animated NS-4s and NS-5s into live-action plates extended with a CG wasteland.

Weta also generated all-digital shots for the following sequence — dubbed ‘Robot Wars’ — in which armies of NS-5s invade the city. The virtual Robot Wars shots had been among the most worrisome to Alex Proyas during the movie’s production. “I was terrified about those all-virtual sequences,” stated Proyas, “worried that there would be something unreal about them. But you buy it completely. You buy that you are in this city and that it’s being invaded by thousands of robots. It was a real surprise to discover how realistic CG can be these days.”

The mastermind of the robot rebellion is ‘VIKI,’ USR’s Virtual Interactive Kinetic Intelligence, which controls all of the company’s — and many of the city’s — operations. In a slavish adherence to the Three Laws of Robotics, VIKI has determined that the only way to truly protect and serve humans is to take control of their lives and, thus, save them from themselves.

Of all the technological wonders in the film, VIKI was the most difficult to conceptualize. “The only thing we knew was that VIKI would be a face,” Patrick Tatopoulos said. “In fact, the original concept was that VIKI would be a big, yellow smiley-face, because she is always so nice and polite — until the end, when you find out that she is up to no good. After thinking about it, Alex felt that it should be a female face, contained in some kind of box. We started developing ideas from there.” One idea that evolved was that ‘branches’ from the central brain would extend throughout the USR building, creating a sense of VIKI’s omnipresence. “In every room and every corridor of the building, there is a 3D cube on which VIKI can appear, connected through channels on the walls — so the presence of VIKI is everywhere. We built those channels practically, incorporating fiber optics into the sets.”

The only other physical manifestations of VIKI on the set were a light setup that threw interactive illumination onto the actors, and a three-foot-square piece of foamcore with a crude face drawn on it. “Sometimes,” said John Nelson, “we’d mount a small monitor to a C-stand, and put the actress doing the voice of VIKI in a booth in the back. That video would be piped into the monitor, so the actors would have ‘VIKI’ there to look at and interact with.” Digital Domain painted out the monitor in post and replaced it with its VIKI effect — the final concept for which was a holographic face within a cube made up of thousands of monitor screens, a literal manifestation of VIKI’s ‘watching’ over every part of the building. “In VIKI’s dormant state, you are looking at a thousand very small video images, moving in 3D on all sides. Then, when VIKI engages you, she comes out of that and forms a virtual face on these screens.”

Digital Domain used the thousands of images from the film it had on line to produce the little scenes projected onto VIKI’s screens. “If you look carefully,” said Erik Nash, “you can see that the

images that make her up are all scenes from the movie. We couldn't use any of the greenscreen material, because the green would pop out and you'd notice these bright green frames; so we culled those out. But we used a lot of other images from the movie, projecting frames onto 3D cubes."

At the film's climax, Spooner climbs to the high-est level of the USR building, into VIKI's core, to inject the central brain with nanites — submicroscopic robots — and, thus, destroy it. The VIKI Level set on which Smith performed was just a wagon-wheel configuration of planks, elevated eight feet above the stage floor and surrounded by green on all sides. In postproduction, Digital Domain extended the minimal set with a digital VIKI core environment. "At VIKI Level," Nelson remarked, "Spooner is on the inside of her, looking out at what looks like the biggest Circuit City in the world, with thousands of little television screens lined up on the walls."

Hundreds of invading NS-5s crawl up the exterior of the USR building, attempting to reach Spooner before he destroys VIKI. The shots made use of a new animation remapper tool developed at Digital Domain. "The NS-5s were animated with a series of animation cycles," said Andy Jones, "but they needed to curve gradually as they crawled up the building, because the building curved at the top. We mapped the animation to a plane, and then warped that plane to make the robots stick to the outside of the building as it curved. Once we had all these guys mapped correctly, we could run them through our crowd system."

Inside VIKI Level, Spooner fires on the NS-5s, blowing them apart and sending them tumbling over the precipice. Animators used a targeting system in Maya to determine the direction and velocity of a hit. "When we clicked on the targeting system," explained Jones, "little crosshairs would come up on the screen. We could rotate the crosshairs around our robot character and decide from what direction we wanted to shoot him. Then we could click 'fire,' and it would stick a tennis ball on the chest and a cone out the back, representing the trajectory and the velocity of the hit. We even had a setting for which gun was used, which would determine what kind of impact it would have on the robot. That was all baked into the animation." Effects animators added debris exploding from the targeted robots — some CG, some generated in an element shoot at Digital Domain — and ran a rag-doll simulation to make them collapse and tumble.

Because of the large numbers of NS-5s in the VIKI Level fight, Digital Domain most often used production plates that had no proxy robot performers in them. "We did have the guys in green there for blocking and rehearsing," recalled Erik Nash, "and we would also shoot a plate with them for cutting purposes; but the plate we put the CG robots into was one that didn't have the guys in the green suits. The exceptions were closer shots of Will Smith in hand-to-hand combat with a robot. In those cases, we would use a plate with a stuntman proxy in it."



Spooner climbs into the VIKI core to shut her down. Working with only a vague description of VIKI as a 'face in a box,' Patrick Tatopoulos, John Nelson and the Digital Domain team collaborated to develop the final VIKI concept — a holographic construct made up entirely of monitor screens. To create the scenes playing out on the screens, Digital Domain culled through thousands of images it had on line from the film, and projected selected frames onto 3D cubes.

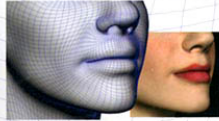
A fight choreographer was on set to orchestrate fight moves for Smith and the robot performers, many of them extended digitally. “The proxy would just do a limited version of the move,” explained Jones, “a kick or something like that, and we would extend it in animation so that it appeared to make contact with Will.” In fight shots requiring more dynamic movement from Spooner, Digital Domain employed a CG double for Will Smith, built from a cyberscan of the actor.

Originally, the film ended with VIKI destroyed and the NS-5s returning to their benign state. Late in postproduction, however, Proyas devised a coda for the movie — an industrial area tableau recalling a scene from one of Sonny’s dreams. “In an earlier scene,” explained Nash, “Sonny had drawn an image from his dream — a figure on a hill, with robots down below looking up at him. In the new ending, we return to that location with all the NS-5s looking up to the figure on the hill — and the figure is Sonny. It is an ending that leaves you thinking, because there are multiple interpretations of it.” The revised ending resulted in two new closeups of Sonny for Digital Domain, and a handful of new NS-5 shots for Weta, which was already creating the industrial area for the earlier massacre scene. Weta incorporated its robots into that digital environment, extended with sand dune and beach elements that John Nelson photographed near the end of postproduction.

The ‘Sonny on a hill’ shot concludes a film that could boast some of the most elegant, most emotionally affecting movie robots ever created. The title character of *I, Robot*, in particular, was a virtuoso display of visual effects artistry — but also a testament to the power of conceptualization and carefully considered designs. “It’s all in the conception,” Alex Proyas concluded. “We’re at a point where you can do anything with effects — but their success still depends on how you conceive them in the first place. If you conceive something that’s impossible to believe, then no matter how well the effects are executed, they will always have that unreality to them. But if you ground your ideas in the real world — even if you are dealing with something as fantastic as robots in the future — the effects will be all that much better.”

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